GENERAL ANATOMY,

APPLIED TO

PHYSIOLOGY AND MEDICINE;

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CAPILLARY SYSTEMS.

THE two great vascular systems, with red and black blood arise and terminate, as we have said, in the capillaries, which form in the lungs, as in all the other parts the limits that separate them, and in which they are changed from one to the other. There are then evidently two capillary systems distinct from each other, and which are even opposite. One, generally spread throughout the body, is the seat of the change of red blood into black. The other, confined wholly to the lungs, exhibits an opposite phenomenon; it is in its divisions that the black blood becomes red.

As the capillaries, which serve for the origin and termination of the black abdominal blood, are intermixed on both sides with those of the general capillary system, since in the abdomen they are continued with the arteries and in the liver give origin to the veins, I shall omit them in these remarks, and attend only to the general and pulmonary capillary systems.

These two capillary systems, the first especially, deserve the more particular consideration, 1st, because the circulation is governed in it by laws wholly different from those of the other parts; 2d, because most of the important functions of life take place there, as secretions, nu-

trition, exhalations, &c.; 3d, because their small tubes are affected on many occasions by diseases, as they are the seat of inflammations, metastases, &c.; 4th, because animal heat is especially produced in these tubes, &c.

The lowest species of animals have in reality only a capillary circulation. Their fluids do not move in great masses, in canals which carry them to all parts of the body, and afterwards bring them back again. There is only an insensible oscillation of these fluids, in tubes of the greatest delicacy and number. This kind of circulation is one of the points of contact, or rather of transition from animals to vegetables, which, destitute of the circulation with a sensible motion, have evidently like the zoophytes, that of an insensible motion and of the capillary vessels.

I shall first examine the general capillary system, and afterwards the pulmonary.

ARTICLE FIRST.

OF THE GENERAL CAPILLARY SYSTEM.

THIS system exists in all the organs; all are in fact composed of an infinity of capillaries, which cross, unite, separate and unite again, by communicating in a thousand ways with each other. The vessels of any considerable size, those among the arteries, in which the blood circulates by the influence of the heart, and those among the veins, which correspond to the first, have really no connexion with the structure of the organs; they wind along their interstices; and are lodged in the cellular texture that separates their lobes; but the capillaries alone essentially make part of these organs, they are so combined with them, that they truly enter into the composition of

their texture. It is in this view, that we may with truth consider the animal body as an assemblage of vessels.

From this first view, it is evident that the extent of the general capillary system is immense, that it embraces all the smallest divisions of our bodies, so that we can hardly conceive of any organic particles united without capillaries. It follows hence, that this system is not only an intermediate one between the arteries and the veins. It is from it, that all the exhalants, all the excretories, &c. go. It furnishes all the vessels that carry nutritive matter to our organs; we ought to describe it then as existing in parts where arteries do not penetrate, as well as in those where they do.

I. *General Division of the Capillaries.*

Since this system is not destined merely to unite the arteries to the veins, and change the black blood to red, it is evident that other fluids besides the blood, must circulate in them; this is in fact what observation proves. There are many parts in the animal economy, in which white fluids alone circulate. We know the hypothetical opinions of Boerhaave upon the white arteries, the decreasing vessels, &c. We shall find these opinions in all books; I shall only say here what accurate observation shows us. That there is in the general capillary system, parts in which the blood especially moves, others pervaded only by white, or greyish fluids, &c. is a thing of inspection, and has no need of proofs. But what is the proportion of these fluids in the different organs? it is this that must be examined; now there are parts where the blood predominates almost exclusively in the capillary system, others where it exists in part, and in which there is a portion of different fluids, others in fine in which these fluids alone are found.

Of the Organs in which the Capillaries contain only Blood.

It appears that in the muscular system, in the spleen, in certain parts of the mucous surfaces, as in the pituitary membrane, &c. the blood so predominates in the capillary tubes, that almost every other fluid is unknown in them; thus fine injections demonstrate few other vessels; the arteries and the veins are seen there in great abundance. The blood, or its colouring matter, is in them, as I shall say, in two different states; in one, it stagnates and serves then to colour the organ; in the other, it circulates and contributes to its nutrition, its excitement, &c.

Of the Organs in which the Capillaries contain Blood and Fluids differing from it.

These organs are the most numerous in the animal economy. The bones, the cellular texture, the serous membranes, a part of the fibrous system, the skin, the vascular parietes, the glands, &c. &c. exhibit this arrangement in a very remarkable manner.

To give an idea of the capillary system in this kind of organs, let us take one in which it is easy to examine it, the serous membranes, for example. When we lay them bare in a living animal, their transparency permits us to see in an evident manner that they contain but very little blood in their capillary system; there are many branches under them, but they appear to be only contiguous; raise, for example, in a small living guinea-pig the peritoneal coat of the stomach; the red arteries, which at first view appeared to be in this coat, remain untouched. These membranes, certainly owe their white or greyish colour to the small quantity of blood they receive from their small vessels, to which the next trunks give rise. After having thus exposed a serous membrane, in order to see the quantity of blood that is found in it in a natural

state, irritate it with any stimulant; at the end of some time, it will be covered by an infinity of reddish streaks, which will be so numerous, that they will change its whiteness into the red colour of the mucous surfaces.

Force fine injections into a dead body, they will so fill the capillary system of the serous surfaces, of those of the peritoneum, for example, that those surfaces will be wholly black, and appear formed only by a net-work of vessels, whilst very few are apparent in the living body, because it is not the blood that fills them. When we cannot open animals to convince us of this, surgical operations, in which the intestines are laid bare, the peritoneum being untouched, wounds of the abdomen, the cesarian operation, &c. will prove incontestably that in the natural state, the blood fills ten and even twenty times less of the vessels, upon the serous surfaces, than injections show us in their texture.

Examine these surfaces in chronic and acute inflammations, of which they are the seat, in the first especially, they exhibit a vascular net-work, so full of blood, that their redness is often deeper than that of the muscles.

All the organs of which I have spoken above, exhibit the same phenomenon. Observe what takes place in the skin; fine injections show there infinitely more vessels than are filled with blood in a natural state; the face of a child well injected, is wholly black. Who does not know that oftentimes from the effect of passion, the blood fills with great rapidity, in the skin of the cheeks, numerous vessels, which in a calm state of mind are not apparent?

Examine the conjunctiva, taken as an example in inflammations; frequently in a short time it changes its white to a bright red, because the blood fills vessels, in which it did not before pass; you can easily distinguish these vessels with the naked eye; you can see that the blood accumulated in this membrane, is not effused, but that it is contained in real vessels.

I take for example the organs that have one of their surfaces free from adhesion, because the state of the capillary system is more easily distinguished in them; but the others present the same phenomenon; we shall see that the cellular texture, certain fibrous organs, &c. &c. examined comparatively, on the one hand in animals that we dissect alive, on the other in an inflammatory state or after fine injections, present a much less number of vessels in the first, than the second case.

It can then be established as an incontestable fact, that in many of the organs of the animal economy, the general capillary system is, in the ordinary state, entered in part by blood, in part by other different fluids, that appear to be white.

The proportions vary singularly; thus the capillary system of the serous membranes contains hardly any blood as I have said; that of the skin more; the mucous surfaces still more, &c. But whatever may be the relation, the difference is not less real in the capillary system.

Perhaps also there are always in this system empty vessels, destined to receive fluids under certain circumstances; thus the urethra, the excretory ducts in certain cases, the orifices of the lacteals in the intervals of digestion, contain nothing. It is difficult to conceive of the rapidity of the passage of the blood in the capillaries of the face, and in those of other parts of the skin, if these vessels contain a fluid, which is to be displaced by the blood. However, nothing but what is founded upon experiment can serve to decide this question.

Of the Organs in which the Capillaries do not contain Blood.

These organs are less numerous than the preceding. They are the tendons, the cartilages, the hair, certain ligaments, &c. Dissected in a living animal, not a single drop of blood escapes from these organs, and yet there is

no doubt that capillaries exist in them; oftentimes very fine injections demonstrate them there. Inflammation, also, frequently fills these capillaries with blood. Into the hair, this fluid enters in the plica polonica, &c. The non-vascular appearance of these organs in the living body, is illusory; it is because their fluids are divided into very small streams, the circulation of them is more slow, and their colour different from the blood, that we cannot perceive them.

II. *Difference of Organs in respect to the number of their Capillaries.*

Though the capillaries exist every where, yet they are more or less numerous in the different organs; in making fine injections, it is easy to be convinced of this. What anatomist has not been struck by the prodigious number of vessels in this way developed, upon the skin, the serous surfaces, the cellular texture, &c. compared with those in the fibrous organs, in the muscles even, &c.?

I have sought for the cause of this difference, and it has not appeared difficult to find it, since where injections develop few capillaries, there is only nutrition going on, as the bones, the muscles, the cartilages, the fibrous bodies, &c. are a constant proof; on the contrary, in all those in which many fluids enter, there are, besides nutrition, other functions, such as exhalation and secretion. Hence why a serous surface, almost as white as a cartilage in the living body, becomes ten times darker than it by the same fine injection; why the skin, compared to the fibrous organs, exhibits the same phenomenon; why in proportion to the arteries that enter a muscle and a gland, the latter admits much more injection than the other.

These observations, which are uniform and invariable, prove that the capillary system is as much more developed in a part, as it has more functions to sustain. Observe in fine, that it is a kind of depot in which the fluids

remain for a certain time, before serving for nutrition, exhalation and secretion. Where these three functions are united, it is necessary that there should be more fluids there, than where only one of them exists; hence more capillary vessels.

The capillary system is not then in the organs in proportion to their size; a portion of the pleura contains more vessels than a tendon that is ten times larger. It is the nutritive substance that fills the place that these vessels do not occupy.

We might, from what has just been said, divide the systems into two classes, from the development of their capillaries; place on one side the serous, the mucous, the glandular, the dermoid, the synovial, the cellular, &c.; on the other the osseous, the cartilaginous, the fibrous, the arterial, the venous, the fibro-cartilaginous, &c. The first class surpasses the second, considerably, in the number of its small vessels. Observe, also, that inflammation, different eruptions, all the affections, in which there is, as it is called, an afflux of humours to a part, are infinitely more frequent in the first than the second class, because all these affections are essentially seated in the capillary system, which is more developed in them.

Asphyxia, apoplexy, and all the affections that make the black blood stagnate in the general capillary system, prove the same thing; in fact, examine the livid head of one who has died of asphyxia, or of apoplexy, you will see that it is especially in the skin and the cellular texture that the blood is arrested; that the muscles, the aponeuroses, exhibit besides the blood ordinarily found in them, only a small quantity of superabundant fluid, in comparison with what there is in the first organs.

Remarks upon Injections.

From all that has been said, it is evident, that fine injections, which form a convenient method of knowing

the capillary system of an organ, cannot show which vessels of this system admit red blood, and which circulate only white fluids. In fact, the injected matter passes equally into each, and we cannot distinguish that, which in the living body is very distinct.

In order to form a precise and accurate idea of the quantity of blood that enters each of the organic systems during life, it is indispensably necessary to dissect those systems during life. I shall frequently have occasion in this work, to make this truth felt, which appears to me to be of much importance in many respects. If a fine injection but partially succeeds, it almost always shows vessels that really exist, but which were not sanguineous during life. Even the coarse injections of our dissecting rooms frequently exhibit these phenomena, especially in the face, the neck, &c.; and much more so, if the matter injected is very delicate, and managed with much address. I cannot conceive why physiologists have always taken as an indication of the blood vessels, the state of injected organs; by opening any part of a living animal, they may clearly see how deceptive this method is.

Injections are of no advantage except in the great vessels, in which the blood circulates in a mass by the influence of the heart; in the capillaries, they do not reach the precise point that exists in nature.

I wish that in dissecting rooms, the pupils, after having dissected the arteries and veins, would finish their labours upon the vessels by the dissection of a living animal, for the purpose of seeing the quantity of blood that each system has in its capillaries; this knowledge is essential to the study of inflammations, fungous tumours, &c. Anatomical cabinets in which preparations are kept, are of no use in this respect; these preparations are more likely to deceive in proportion as the injections have succeeded well.

III. *Of the proportions which exist in the Capillaries between the Blood and the Fluids that differ from it.*

In the organs in which the blood, or the white fluids differing from it, alone enter, there can be no variety in the proportions; but the varieties are frequent in those where these fluids enter at the same time. In the serous, the dermoid, the mucous systems, &c. there are sometimes more, sometimes less small vessels filled with blood; the cheeks, of which I have spoken, are a remarkable example of this. The least emotion, the slightest agitation, or a motion a little too violent, accumulates, diminishes, and varies, in a thousand different ways, the quantity of blood in them. The whole exterior of the skin exhibits the same phenomenon, though less frequently. When this organ is irritated or excited at any point, it immediately reddens; it becomes white if it is compressed. Cold and heat uniformly produce analogous varieties, when the change from one to the other is sudden. All the mucous surfaces exhibit the same arrangement; see the glans in the erection of coition, or in the flaccidity that succeeds it; the difference in the quantity of the blood that this external membrane contains, is very evident. Lay bare a serous surface; at first white, soon there will be numerous red streaks. If we could see the capillaries of the glands, I presume that we should find the quantity of blood variable in these vessels, and that during the time that the secreted fluids are poured out in abundance, their system would be more copiously supplied than at any of the time when it furnishes the materials of the secretions. Why are not the kidnies and the liver subject to the same varieties in the quantity of their blood, as the surface of the skin? When, by a violent motion, sweat pours out in abundance, and the external surface of the body looks more red, does it not indicate that the blood is there in a greater proportion?

There are two things to be distinguished, however, upon this subject; it is only when the copious secretions arise from an increase of life, that a greater afflux of blood is supposed to take place in the glandular system. When this increased secretion proceeds from a want of vital energy, the blood is not in greater quantity in the gland. The same observation applies to exhalation; thus, in the above case, in the commencement of fever, &c. more blood enters the skin; but when the sweat arises from weakness, as in phthisis, &c. there is not this accumulation of blood in the capillary system. But this deserves a longer explanation.

Different proportions of Blood in the Capillaries, according as the Secretions and Exhalations are active or passive.

I call those exhalations and secretions active, which are preceded and accompanied by an evident development of vital forces; and those passive which exhibit an opposite phenomenon. If we examine the phenomena of the animal economy, it will be easy to see this distinction, which appears to me essential in diseases; now, in whatever organ you study it, you will always see every active exhalation or secretion preceded by a greater afflux of blood to the part; all passive exhalations and secretions present an opposite phenomenon. Let us begin with exhalations.

1st. Cutaneous exhalation is active from violent running, or a paroxysm of fever, as I have said, from the action of caloric upon the body, hard work, &c.; the skin is then more expanded and deeper coloured; more blood enters it, &c. This excitement of the skin makes it more fit to be influenced by external agents, and to influence in its turn all the other organs. It is the suppression of these transpirations which causes so many accidents in the animal economy. Observe, on the contrary,

the complexion of the body in phthisical sweats, in those produced by internal suppurations, in those that are the effect of fear, in all those that are called colliquative, &c.; this complexion is more pale than in a natural state; it is not capable of being influenced, because its vital activity is then small, and its forces languish.

2d. In the exhalations of the serous surfaces, there are some that are essentially active; such is that of pus; for we shall see that the formation of this fluid upon these membranes is without any kind of erosion, that it flows evidently from the exhalants, instead of serum; very often even it flows at the same time. Nothing is more frequent, in fact, than the milky or purulent serum that is found in the peritoneum, the pleura, &c. whether the fluids are exactly mixed, or the pus floats in flakes in the serum. Now this active exhalation of serum or of pus, which appears to be here principally coagulated albumen, this exhalation, I say, is evidently preceded by a considerable accumulation of blood in the capillary system, an accumulation which constitutes inflammation, and without which exhalation cannot take place. Observe, on the contrary, serous exhalation, increased by the weakness that any organic disease gives to the serous membranes; to furnish this fluid, the blood is never accumulated in them in greater quantity. Open the membranous sacs, after the diseases of the heart, the womb, the lungs, the liver, the spleen, &c. you will find them full of water, but more diaphanous than usual, because they have received less blood.

3d. What I have said of the serous exhalations, must be said of the cellular; some of them are active, such as those of pus and the serum that sometimes accompanies it; others are passive, as the leucophlegmasia after organic diseases. The same observation is to be made as before; there is an accumulation of blood in the capillary system in the first kind, a diminution of this fluid in the

second. Observe the fatty exhalation; a man in health who is very fat, has a rosy colour upon the integuments distended with fat, which indicates the abundance of blood in the capillary system. On the contrary, in certain cases of sudden corpulency after diseases, in that which is called false fat, and accompanies weakness, a general paleness corresponding with the fatty bloating, indicates the absence of the sanguineous fluid.

4th. Mucous exhalations present also an analogous phenomenon. I shall prove soon that the hemorrhages from the mucous surfaces are real exhalations; now some of them are active, a name which Pinel has given them in his Nosography; these are the nasal, pulmonary, gastric, uterine hemorrhages, &c. of young people and even of adults. All these hemorrhages are accompanied by a local increase of action, by greater heat, by a deeper colour of the mucous membrane, by the greater abundance of blood in the capillary system. Who does not know, that Galen predicted a hemorrhage from the redness which he saw upon the nose and the eye of the patient? On the other hand, observe the hemorrhages of the mucous surfaces, which take place after long diseases, hemoptysis, which terminates the diseases of the heart, hematemesis, the effect of organic derangement of the liver, hemorrhages from the intestinal canal, so frequent at the end of all the long organic diseases of the abdomen, &c. nasal hemorrhages in certain low fevers, those which take place in scurvy from the different mucous surfaces, the gums especially, &c. all these hemorrhages, which are truly passive are not accompanied by this preliminary sanguineous congestion in the capillaries, by this increased activity of vital action; it might be said that it is the blood, which transudes, as in the dead body, through the pores, that have not power to retain it. This distinction is so true, that without making a theory of it, physicians conform to it in their practice. We bleed to arrest an

active hemoptysis, but would you bleed to stop that which comes on in the chronic diseases of the thorax? The same observation applies to all the hemorrhages; they require means wholly opposite, according as they are active or passive; a remark moreover that is applicable to all diseases that have increased exhalations or secretions, whatever may be their seat. It is not the phenomenon that we are to resist, but the cause that has produced it. We diminish the forces, when serum is accumulated in the thorax, from a pleurisy; we increase them, when it accumulates from a disease of the heart, the lungs, &c.

What I have just said of exhalations applies to secretions. The mucous glands pour out a greater quantity of fluids in two ways, sometimes from irritation, sometimes from the want of force. When this happens in the intestines, there results from it in the first case a diarrhœa from irritation, in the second a colliquative one. Now it appears that the blood enters the gland in greater abundance in the one than the other case. Its increase takes place undoubtedly in most acute catarrhs, in which there is active secretion of mucus; its diminution or at least its want of increase is not less sensible in many chronic catarrhs, in which we may consider the secretion as passive. We know that the abundance of urine, of bile, sometimes supposes an increased, sometimes a diminished action of the kidney and the liver. Is there not a superabundance of semen from excess of vitality, and an unnatural flow from weakness? All the secreted fluids have the same arrangement: now according to these two opposite causes of the superabundance of the secreted fluids, the capillary system of the glands is certainly penetrated with a different quantity of blood. Though the phenomenon be the same, the treatment in the diseases in which it is manifest, is as in the preceding cases, wholly opposite, according as the local increase or diminution of life concurs to produce it.

Consequences of the preceding Remarks.

From all that I have said, it is evident that in the organs whose capillary system contains in part blood, and in part different fluids, the proportion of the first to the others is infinitely variable; that a thousand causes in a state of health, as in that of disease, by bringing to the organ more or less blood, can fill more or less its capillary system.

The trunks and branches that go to an organ, are they more or less dilated, according as the capillary system of this organ is more or less filled with blood? For example, when the mucous glands pour out fluid in the greatest quantity, are the neighbouring branches more full? Some experiments that I shall mention hereafter do not seem to prove it.

IV. *Of the Anastomoses of the General Capillary System.*

All that has been said evidently supposes a free communication established between all the parts of the capillary system; this communication is in fact clearly demonstrated by observation. When we examine a serous injected surface, of which the capillary system is full, we see that this system is a real net-work with fine meshes, and in which no vessel runs a distance of more than two lines, without communicating with others. The passage then, is constantly open between the portion that receives blood, and that which admits fluids differing from it. The same arrangement exists in the dermoid system, in the origins of the mucous, &c. and in general in all those in which the capillary system contains blood and white fluids.

On the other hand, the organs in which we find only white fluids, evidently communicate with those that are near them, and in which there is blood; those in which blood alone flows, have the same arrangement.

The capillary system must then be considered as a general net-work, spread throughout the body, which communicates on one side in every organ, and on the other from one organ to another. In this respect there is from the head to the feet a general anastomosis, a free communication for the fluids. It is in this way that we can conceive of the permeability of the body, and not from the cellular texture, in which the serous and fatty fluids alone stagnate.

As the arteries enter the capillary system, and as the veins, the exhalants, the secretories, go from it, it is evident from this manner of considering the capillary system, that all these vessels ought to communicate with each other; that by pushing a fine fluid into the arteries, it should go out by the excretories, the exhalants, and return by the veins, after having gone through the capillary system; this is in fact what takes place. In this respect, a thousand ways are constantly open for the blood to escape from its vessels, which communicate thus everywhere without, and do not present any mechanical obstacle to the blood in their cavity, which life alone retains within the limits of its circulation. The oozings after death through the exhalants, the excretories and the veins, are so well known, so many anatomists have related examples of them, that I think it unnecessary to give them in detail here. We have seen, then, fine injections pour out upon the serous membranes, upon the pericardium, the pleura, the peritoneum, &c. transude upon the mucous surfaces, even upon the skin. We have seen them flow through the ureters, the pancreatic, biliary, salivary ducts, &c. Haller, in the article upon each organ, has not failed to relate examples of this sort, which prove the communication of the arteries with all the other vessels, by means of the capillary net-work. What anatomist has not sometimes made even coarse injections return by the veins? The communication of

these vessels with the arteries, through the capillary system, is now an anatomical axiom. At one time, it arrested much attention. It has been asked, if there was any thing intermediate between the arteries and the veins; inspection proves that the capillary system alone is there.

Hence it is necessary to represent the capillary system as a kind of general reservoir, in which the arteries enter on one side, and from which go out on the other side, in all the organs, the nutritive exhalants, in some, certain particular exhalants, as those of the sweat, the lymph, the fat, &c. in others the secretory vessels, &c. It is a common reservoir, if I may so express myself, in which the red blood enters, and from which the black blood, the exhaled, the secreted fluids, &c. go out.

This idea is not hypothetical; the injections of which I have spoken are the most evident proof of it. Let it not be said that it is a transudation after death, analogous to that of the bile through the gall-bladder: if it were so, not only the fine fluids injected would go out by the excretories and the exhalants, and return by the veins; but in oozing through the pores, they would fill the whole cellular texture. On the contrary, nothing escapes into the cellular texture, around the vessels by which the injection passes; there is then a continuity of tubes from the artery which has received the fluid, to the excretory, the exhalant, or the vein which transmits it.

These are the communications of the capillary system that explain how the skin becomes livid on the place on which a dead body has for a long time lain, as on the back, for example; how by turning a dead body, so that the head may hang down, it becomes full of fluid; how, on the contrary, by placing upright the body of one dead from apoplexy, asphyxia, &c. the capillary system of the face is freed in a great measure from the blood it contained; how an erysipelas disappears on a dead body, when

the blood, arrested during life on a part of the skin, by the vital action, is spread after death to all the surrounding parts; how every kind of analogous redness of the skin, and even of the serous surfaces, disappears because the blood goes by the communications of the capillary system to the neighbouring organs. During life the tonic action retains the fluid in a determinate part; abandoned to its gravity, and other physical causes, after death, it soon disappears from the part in which it was accumulated, on account of the innumerable communications of the general capillary system.

I would observe to those who examine dead bodies, that these considerations are very important. Thus we must not judge of the quantity of blood which penetrated the inflamed peritoneum or pleura, by what is seen twenty-four hours after death; local irritation was a permanent cause that fixed the blood in the part; this cause having ceased, it escapes from it. A serous membrane may have been very much inflamed during life, and yet exhibit almost its natural appearance after death; as it is in erysipelas. I should have been often tempted from opening dead bodies, to deny the existence of an affection which had been real. The same remark applies to the inflamed cellular texture, the mucous surfaces, &c. Examine a subject that has died of angina, which during life gave the deepest red colour to the pillars of the velum pendulum pelati, to the velum itself and the whole pharynx; after death, the parts assume nearly their natural colour.

I would observe that in this respect it is necessary to distinguish acute from chronic affections. In the chronic inflammations, for example, of the pleura, of the peritoneum, &c. the redness continues after death, because the blood is combined, as it were, with the organ; it makes a part of it, as it makes a part of the muscles in a natural state. So the chronic affections of the skin, of the mucous surfaces, retain after death nearly the same blood,

that they had during life; whereas in acute affections, the blood retained for a time by irritation, escapes when life has ceased, upon which this irritation depended. These principles can be applied to many diseases; I repeat it, they are of great importance in examining bodies. The neglect of them has often led me into an error, upon the degree and even the existence of acute inflammations, of which the organs that I examined had been the seat.

V. *How, notwithstanding the general communication of the Capillary System, the Blood and the Fluids differing from it, remain separate.*

Since in the dead body, and consequently during life, there is in the capillary system no organic obstacle to the communication of the fluids through its small branches; since the general net-work that these vessels form is everywhere free, how does it happen that the blood does not pass into the part destined to the white fluids? how is it that these do not enter where the blood is to circulate? Why does not this fluid go out by the exhalants and the excretories, since these tubes communicate with the arteries by the anastomoses of the capillary system? This depends wholly upon the relation which exists between the organic sensibility of each part of the capillary system, and the fluid that it contains. That which carries the blood, finds in all the other fluids irritants that make it contract at their approach; and reciprocally, where the other fluids belong, the blood would be a foreign fluid. Why does the trachea admit air, and reject every other fluid? Why do the lacteals choose only chyle from the contents of the intestines? Why does the skin absorb certain substances, and repel others, &c.? It all depends upon this, that each part, each portion of an organ, every organic particle, has its own sensibility, which is in relation only with one substance, and repels others.

But as this kind of sensibility is remarkably subject to vary, its relation to substances foreign to the organ changes also; thus the part of the capillary system which rejected blood, admits it at the moment when its sensibility has been increased. Irritate a part of the skin, it reddens in an instant; the blood flows there; while the irritation continues, it remains; when it ceases, it disappears. Whatever be the external means which raise the cutaneous or mucous sensibility, we observe the same phenomenon. We can in this way bring more or less blood into some parts of the capillary system. Bring the hand to the fire, the heat exalts the sensibility of its system, more blood enters it; take it away, this property resumes its natural type, and the blood is brought back to its ordinary quantity. The internal organs which are subjected less to the causes of excitement, have less varieties in their capillary system; yet, however, there are many, and all arise from the same principle.

A series of organized tubes are unlike an assemblage of inert ones. These last require mechanical obstacles to prevent the communication of fluids with each other; where there is a communication between the tubes, there is a communication in the fluids. On the contrary, in the living economy, it is the peculiar vitality with which each tube is animated, which serves for an obstacle and a limit to the different fluids; this vitality performs the part of different machines that we place in the communicating tubes, to separate them from each other. Every organized vessel is then truly active; it admits or rejects fluids which enter there, according as it is able or not to support their presence. Disproportion of capacity has nothing to do with this phenomenon; a vessel may have more than four times the capacity of the particles of a fluid, and yet refuse to admit them, if this fluid is repugnant to its sensibility. It is in this point of view that the theory of Boerhaave has a great defect.

At the period in which this physician wrote, the vital forces had not been analyzed. It was necessary to employ physical forces to explain vital phenomena; hence it is not astonishing that all his theories are so incoherent. In fact, theories in the vital phenomena borrowed from physical forces, exhibit the same inadequacy, as those would in the physical phenomena borrowed from vital laws. What would you say, if in explaining the motion of the planets, rivers, &c. they should talk of irritability and sensibility? you would think it absurd; it is equally absurd, in explaining the animal functions, to talk of gravity, impulse, inequality of the capacity of the tubes, &c.

Observe, that the physical sciences made no progress until they analyzed the simple laws that preside over their innumerable phenomena. Observe also, that medical and physiological science was not accurately explained, until the vital laws were analyzed, and it was shown that they were everywhere the principles of the phenomena. See with what ease all those of the secretions, exhalations, absorptions, inflammation, capillary circulation, &c. are referred to the same principles, flow from the same data, by deriving them all from their real cause, the different modifications of the sensibility of the organs which execute them. On the contrary, see how each presented a new difficulty, when the mechanical causes were employed to explain them.

From what has been said, it is then evident, that in the innumerable variations of which the fluids of the capillary system are susceptible, in the different portions of the system which they fill, there is always antecedent variations in the sensibility of the vascular parietes; these varieties produce the first.

It is especially in the capillary system and its circulation, that the variations of the organic sensibility of the vessels produce varieties in the course of the fluids; for

as I have observed, in the great arterial and venous trunks, in the heart, &c. the fluids are in too large masses, and they are agitated by too strong a motion, to be thus immediately subjected to the influence of the vascular parietes. Thus when nature wishes to prevent the fluids from communicating in the trunks, it places among them valves, or other analogous obstacles, which become useless in the capillary system.

Though the anatomical arrangement be the same in the living and the dead body, there is then a very great difference in the course through the capillary system, in one and the other. Push, into the aorta of an animal in whom you destroy life by opening this artery to fix in it a syringe, different fine fluids; you will never see them fill the capillary system, pour out by the exhalants, the excretories, &c. as when the subject has been some hours deprived of life. The organic sensibility inherent in the parts repels the injection; it can only circulate in the great trunks, in which there is a large space. I have injected, with other views, a great number of times, fluids by the arteries and the veins; now, the capillary system is never filled with these fluids; they circulate only in the great vessels, when the animal can bear them. Mr. Buniva has also made comparative experiments with injections upon living animals and those deprived of life; he has experienced in the first a resistance which he has not found in the other; now this resistance is in the capillary system, whose vessels refuse to admit a fluid to which their organic sensibility is not accommodated.

VI. *Consequences of the preceding principles, in relation to Inflammation.*

From what has been said thus far, it is easy, I think, to understand what takes place in the inflammatory phenomena, considered in general.

If a part be irritated in any manner, immediately its organic sensibility is altered, and increased. Without previous connexion with the blood, the capillary system is then placed in relation with it; it as it were calls it there; it flows there and remains accumulated until the organic sensibility returns to its natural type.

The entrance of the blood into the capillary system is then a secondary effect of inflammation. The principal phenomenon, that which is the cause of all the others, is the local irritation which has changed the organic sensibility; now this local irritation may be produced in different ways; 1st, by an irritant immediately applied, as a straw upon the conjunctiva, cantharides upon the skin, acrid vapours upon the mucous surface of the bronchia or the nasal cavities, atmospheric air upon any internal organ laid bare, as we see in wounds, &c.; 2d, by continuity of organs, as when a part of the skin, of the pleura, &c. being inflamed, those that are near it are also affected, and the blood flows there, as when one organ is diseased, that which is near it becomes so by the cellular communications; 3d, by sympathies; thus the skin being seized with cold, the pleura is sympathetically affected; its organic sensibility is increased, the blood immediately enters it from every part. When this property is raised in one of these three ways in the capillary system, the phenomena that result from it are the same. For example, when in the pleura it is raised because the air is in contact with this membrane, because the lungs that it covers have been first affected, or because cold has seized upon the skin in sweat, the effect is nearly analogous, as it respects the entrance of the blood in the capillary system.

It is then the change that takes place in the organic sensibility, that constitutes the essence and the principle of the disease; it is this change which makes a pain more or less severe soon felt in the part; then the sensibility that was organic, becomes animal. The part was before

sensible to the impression of the blood, but did not transmit this impression to the brain; then it transmits it, and this impression becomes painful. Irritate the healthy pleura in a living animal; it does not suffer; irritate it on the contrary during inflammation, and it gives signs of the most acute pain. Who does not know that most often and almost always, a pain more or less acute is perceived in the part, some time before it becomes red? Now this pain is the indication of the alteration that the organic sensibility undergoes; this alteration exists some time, often without producing an effect; this effect, which is especially the afflux of blood, is subsequent.

It is the same of heat. I shall say hereafter how it is produced. It is sufficient now to show that it is, like the passage of the blood in the capillary system, only an effect of the change that has taken place in the organic sensibility of the part; now, this is evident, since it is always consequent upon this change.

There happens then in inflammation exactly the reverse of what Boerhaave thought. The blood accumulated according to him, in the capillary vessels, and pushed *à tergo* by the heart, as he termed it, was truly the immediate cause of the affection, whereas, from what I have said, it is only the effect.

If we reflect a little upon the innumerable varieties of the causes which can alter the organic sensibility of the capillary system, it will be easy to understand of what infinite varieties inflammation is susceptible, from the momentary blush that comes and goes in the cheeks, to the most serious phlegmon and erysipelas. We might make a scale of the degrees of inflammation. By taking the cutaneous, for example, we should see at the bottom the redness that arises and disappears suddenly by the least external excitement upon the dermoid system, which we can produce at will, and in which there is only an afflux of blood: then those that are a little more intense, which occasion

cutaneous efflorescences of some hours, but without fever; then those that continue for a day, with which there is some fever; then erysipelas of the first order; then that which is more intense, and which gangrene soon terminates. All these different degrees do not suppose a different nature in the disease; the principle of them is always the same; there is always, 1st, an antecedent increase of organic sensibility, or alteration of this property; 2d, afflux of the blood only if the increase is not great, afflux of the blood, heat, pulsation, &c. if it is. As to fever, it is a phenomenon common to every severe, acute local affection; it appears to depend on the singular relation which connects the heart with all parts; it has nothing peculiar in inflammation, but the particular modification it receives from it.

The afflux of the blood in an irritated part takes place in inflammation, as in an incision. In this the divided point has been irritated by the instrument; soon the whole blood in the neighbourhood flows there and escapes by the wound. This afflux is so evident a result of irritation, that in a slight incision, the blood scarcely flows at the instant of the division of the integuments, because there is but little of this fluid at the divided place; but a moment after, the irritation which has been felt, produces its effect, and it flows in a quantity disproportioned to the incision.

When the alteration of the organic sensibility which produces inflammation, has no varieties except in its intensity, the inflammation itself differs only in degree. But the nature of the alteration is oftentimes different; a feeble character is frequently united with it; the part has then less redness, heat, &c. Other modifications are also observed; now all these depend upon the difference of the alterations that the organic sensibility experiences; at least these alterations always precede them.

The influence of these alterations is not less evident when inflammation terminates, than when it begins. If the or-

ganic sensibility has been so raised, that it is as it were exhausted, then the solid dies, and the fluid, which is no longer in a living organ, soon becomes putrid. Examine the phenomena of every gangrene; putrefaction is certainly only a consequence; there is always, 1st, a desertion of the solids by the vital forces; 2d, putrefaction of the fluids. The first is never a consequence of the second. When the organic sensibility begins to diminish, the blood brought there by inflammation is already susceptible of putrefaction; but the defect of tone in the solid always precedes. There is this local phenomenon, as well as the general, in putrid fever. It is incontestable that in this fever, the blood has a tendency to be decomposed, to become putrid; I will say further, that it often exhibits a commencing putrefaction. The index of the alteration of this fluid is always the general state of the forces of the solids; these have first lost their spring; the symptoms of weakness are evident before those of putridity. All the animal fluids tend naturally to putrefaction, which takes place inevitably when life abandons the solids in which they circulate. In proportion as the forces diminish in the solids, this tendency is manifested. A commencement of putrefaction in the fluids during life, is not a general phenomenon more improbable than the local phenomenon of which we have spoken, viz. that the blood of an inflamed part begins to putrefy and the part consequently becomes fetid, before the organic sensibility has entirely abandoned the solid. It is only when this ceases, that this putrefaction becomes complete; but then it is extremely rapid, because it had commenced during life. So bodies that have died of putrid fevers decompose with a rapidity far surpassing those that have died of other diseases, because putrefaction had really commenced before death.

Inflammation with a livid colour, small degree of heat, prostration of the forces in the part, and termination by gangrene, is evidently to well marked adynamic fever, what

phlegmon is to inflammatory fever, what irritation of the primæ viæ, which is called bilious affection, is to the meningo-gastric fever, &c. I think if we examine attentively local affections and general fevers, we shall always find a particular kind of fever corresponding in its nature to a particular kind of local affection. But let us return to inflammation.

If it terminates by suppuration, it is evident that there is a new alteration of the organic sensibility to produce pus. The same thing in scirrhus. The termination by resolution takes place when this sensibility returns to its natural type. Examine well the inflammatory phenomena in their succession; you will see, that always a particular state in this property, precedes the changes they exhibit.

When our medicaments are applied upon an inflamed part, it is not upon the blood that they act; it is not by lessening the heat, or relaxing. The expressions *to soften, unbend* and *relax* the solids, are inaccurate, because they are borrowed from physical phenomena. We relax, we soften dry leather by moistening it; but we only act upon the living organs, by modifying their vital properties. Observe that though we already begin to recognize the empire of these properties in diseases, medical language is still wholly borrowed from theories which employ physical principles in the explanation of morbid phenomena. We have arrived at a period when the manner of expressing ourselves upon these phenomena should be changed; I do not here speak of the names of diseases. Certainly every emollient, astringent, discutient, relaxing, tonic, medicament, &c. employed with different views upon an inflamed part, only acts by modifying differently from what it was, organic sensibility. It is thus that our medicaments cure or often aggravate diseases.

From what has been said, it is evident that the solids perform the first part in inflammations, and the fluids only the second. Modern authors have perceived this truth,

and they have immediately assigned an important part, in this respect, to the nerves; but we have seen that these appear foreign to organic sensibility, that they are so even after the most rigorous observation. The nervous influence, that at least which we know in other parts, is, in inflammation, as in secretion, exhalation and nutrition, almost entirely wanting. There is in this affection, unalteration of the organic sensibility, and this is every thing.

The kind of blood varies in inflammation, and in this respect, I think the following rule is generally uniform; whenever the organic sensibility is much raised, the life augmented and there is an increase of forces in the inflamed part, then it is the red blood that remains in the capillary system; then there is always great heat there. On the contrary, when the inflammation approaches the putrid character, the part becomes of a dull and livid colour; the capillaries appear to be filled with black blood; the heat is less. In general, a bright colour, in all eruptions analogous to inflammatory tumours, announces the increase of the organic sensibility. A livid colour, on the other hand, indicates its prostration; petechiæ are livid; scorbutic blotches are so; a livid colour in tumours is the forerunner of gangrene. Do you wish to know when cold acts as a stimulant? It is when it reddens the end of the nose, the ears, &c. When these parts become livid, other phenomena announce at the same time, that its action is sedative. This is supported by my experiments upon life and death, which have proved that the black blood everywhere interrupts the functions, weakens, annihilates even the motion of the parts, when it is brought to them by the arteries.

Differences of Inflammation, according to the different Systems.

From what has been said upon inflammation, it appears that it has for its seat the capillary system, for its princi-

ple an alteration in the organic sensibility of this system, for its effect the afflux of blood into vessels in which it did not before circulate, a consequent increase of caloric, &c. Now where the capillary system is more developed, where the organic sensibility is greater, inflammation ought to be more frequent; and this is the case. It is especially in the cellular, serous, mucous and dermoid systems that we observe it; fine injections demonstrate in these systems a capillary net-work infinitely superior to that of the others. Besides, as if there is not only nutrition, but also exhalation and oftentimes secretion in these systems, there must be more organic sensibility, a property from which all these functions are derived.

On the contrary, inflammation is rare in the muscular, osseous, cartilaginous, fibrous, arterial, venous systems, &c. where there are but few capillaries, and where the organic sensibility presiding only over nutrition, is necessarily found in a less degree.

Besides, as the capillaries make an integral part of the system where they are found, and as each system has its peculiar kind of organic sensibility, it is evident that they ought to partake of this kind; now as it is upon this property that all the inflammatory phenomena depend, they ought to present an aspect wholly different in each system. This is what we shall be convinced is the case by an examination of each. I shall only present here generally, that essential point of view, upon which authors have not insisted.

Let us take first the systems most exposed to inflammation; we shall see that phlegmon is the inflammatory kind of the cellular, erysipelas that of the dermoid, and catarrh that of the mucous. We have not yet a general name to express that of the serous; but who does not know how it differs from the others?

In the systems rarely subject to inflammation, we know this affection infinitely less than in the preceding; but

there is no doubt that it differs essentially. Compare the length and permanency of that of the bones, with the rapidity and disposition to change of that of the muscles, or rather of the fibrous bodies, in rheumatism.

The results of inflammation do not vary less than its nature; if resolution does not take place, each has its own mode of suppuration. Compare the pus of erysipelas, that of phlegmon, the milky or flocculent fluid of the serous membranes, the whitish or greyish humour, of a mucous consistence, that escapes from the membranes of the same name after catarrh, the blackish sanies of the bones in suppuration, &c. We shall see that some organs, as the fibrous bodies, do not suppurate.

Gangrene once taken place, is everywhere the same, since it is only the absence of life, and all dead organs have the same properties. But according to the sum of organic sensibility which each system has, it is more or less disposed to die after inflammation, in the midst of others which retain their life. Who does not know that the carbuncle which soon kills the part it seizes, only attacks certain systems; that the osseous, the cartilaginous, the nervous, &c. are always exempt from it?

The essential fault of every medical doctrine is that of considering diseases too abstractedly; they are so modified in each system, that their aspect is wholly different. If I may be allowed the expression, it is always the same individual, but in entering each system, it has a different appearance there, so that often you cannot recognize it. When will medicine be so far advanced that the treatment will correspond with these varieties? There should certainly be a general treatment of inflammation; but it should be modified differently, according as we apply it to phlegmon, erysipelas, catarrh, &c.

This then is a very evident proof of that peculiar character which inflammation takes in each part. We know with what ease and rapidity the blood flows to any part

of the skin in consequence of irritation there; prick or rub briskly a part of this organ, it reddens in a moment. This takes place also, though less sensibly, on the mucous surfaces. This is not equally seen upon the serous; I have frequently ascertained this on living animals, when I have laid bare these surfaces and irritated them in different ways. The afflux of the blood does not immediately follow the irritation; there is always an interval between one and the other, never less than an hour.

VII. *Structure, and Properties of the Capillaries.*

What is the structure of the capillaries? So great is their tenuity that we evidently cannot have upon this point, any kind of data founded upon experiment and observation. Only it is very probable, it is even certain, that this structure is modified differently in each organ, that it is not the same in the tendons, the aponeuroses, the muscles, &c. that it really partakes of the nature of the organ of which it makes an integral part.

The membrane which lines the excretories, the arteries, the veins, the exhalants, vessels which go into the system of the capillaries or come out of it, is very like that of these capillaries; but it is not certainly the same.

It is the diversity in the structure of the capillaries, according to the organs in which they are found, which has an essential influence upon the difference which the vital properties exhibit, particularly the organic sensibility and the insensible organic contractility in each system in which we examine them; hence peculiar modifications in all those diseases over which these properties preside, and which are seated especially in the capillaries, such as inflammations, tumours, hemorrhages, &c. &c.

The difference in structure of the capillary system, sometimes becomes manifest to the eye. Thus the spleen, the corpus cavernosum, instead of presenting, like the serous surfaces, a vascular net-work in which the blood

oscillates in different directions, according to the motion it receives, exhibit only spongy, cancellated textures, whose nature is but little known, in which the blood appears often to stagnate, instead of moving, &c.

VIII. *Of the Circulation of the Capillaries.*

The circulatory phenomena are of two kinds in the capillary system: 1st, there is the motion of the fluids; 2d, the alterations which they undergo.

Motion of the Fluids in the Capillary System.

These fluids are, 1st, the blood; 2d, others differing from it in their composition, though we only know their differences of appearance. Let us examine the laws of the motion of each kind.

The blood, after it has entered the capillary system, is evidently beyond the influence of the heart, and only circulates by that of the tonic forces, or the insensible contractility of the part. If we examine the phenomena of this capillary system but little, we shall be easily convinced of this truth, which Bordeu first taught. The capillary system is really the boundary, beyond which the influence of the heart does not extend. Hence why all the vessels that go out of this system, exhibit in the fluid they contain a motion that does not correspond with that of the arteries that go to it. 1st. After what we have said, there is no doubt of this, as it regards the veins. 2d. It is also true as it respects the excretories. The increase of secretions does not correspond with the increase of the action of the heart, nor does their diminution with the diminution of the pulsations. Who does not know, on the contrary, that often in a violent paroxysm of fever, in which the agitation of the arterial blood is very great, all the glands seem to shut up their ducts and not to pour out any fluid? 3d. It is the same with all the exhalations; it is not when a fever is the greatest, that

we sweat the most, but when it is somewhat diminished. Hemorrhages are evidently but an exhalation ; now who does not know, that the pulse is often very weak, when the blood flows abundantly from the mucous surfaces of the womb, the nostrils, the bronchia, &c. ? Who does not know on the contrary that in extreme agitations of the heart, most often the blood does not flow by the exhalants? Is the quickness of the pulse increased during menstruation ? It is the redness of the capillary system, the abundance of the blood of this system, which is often, as I have said, the forerunner of active hemorrhages ; but it is never the increase of the action of the heart. Oftentimes fungous tumours, soft flesh that shoots up in wounds of a bad nature, polypi, &c. pour out blood ; the heart has nothing to do with these hemorrhages, they come evidently from the capillary system. Who does not know, that frequently when the exhalants pour out copiously serous fluids upon the membrane of that name, in the production of dropsies, the heart is, like all the other parts, in a state of real inertia ?

Since then all the vessels going from the capillary system exhibit in their motions no sort of harmony with those of the heart, it is evident that the influence of this organ is interrupted, is terminated at the capillary system.

Observe nutrition ; it is clearly the capillary system that distributes everywhere the materials that it has received by the impulse of the heart ; now the influence of this does not extend to the place where the nutritive matter is deposited. In fact, its impulse everywhere equal and uniform, pushes the blood with nearly an equal force to all parts, with some exceptions in the foetus. Now nutrition is on the contrary extremely unequal ; at one age, it is one part that takes more increase, consequently receives more nutritive matter ; at another age, it is another organ. This inequality, is the first and principal phenomenon of growth.

How can we reconcile with the sole and uniform impulse of the heart in all parts, inflammation, the production of herpes, of different eruptions, &c. which appear in some places? Would inflammation exhibit so many aspects, according to the system it seizes, if the heart alone presided over its development? All the difference between catarrh, erysipelas, phlegmon, &c. would disappear; and there would be only what arose from being nearer, or further from the heart.

Let us cease then to consider this organ as the sole agent which presides over the motion of the great vessels and the small, which, in these last, driving the blood abundantly to a part, produces there inflammation, which by its impulse causes the different cutaneous eruptions, secretions, exhalations, &c. The whole doctrine of the mechanicians rested, as we know, upon the great extent which they gave to the movements of the heart.

There are evidently two kinds of diseases in relation to the circulation; 1st, those that affect the general; 2d, those that affect the capillary circulation. Different fevers form especially the first kind. Different eruptions, tumours, inflammations, &c. produce the second; now, though many relations connect the second with the first, it is not essentially dependant upon it; the following is the proof of this; fevers can evidently only exist in animals with great vessels, in those in which the fluids move in a mass; they cannot take place in zoophytes and plants, which have only a capillary circulation; yet these last classes of animals and all vegetables are subject to all the affections that disturb the capillary circulation. Thus we see upon plants many tumours; their wounds unite; two portions even contract adhesions, as a graft proves. The diseases of their capillary system are no doubt different from those of animals in their progress and their nature; but they exhibit always the same general character, because they are derived from the same properties, organic sensibility and insensible contractility.

Since the diseases of the capillary system are not essentially connected with those of the general vascular system, they are not then dependant on it; the circulation of the first is but indirectly subordinate to that of the second. Hence why the two circulations can be separate; why more than half of the organized beings have only the capillary. This is the most important, since it immediately pours out the materials of nutrition, of exhalations, of absorption: thus it exists in all organized beings. We cannot conceive of any one without it, because we cannot conceive of any one that is not continually composed and decomposed by nutrition.

From what we have thus far said, it is evident, that the blood after it has arrived in the capillary system, is moved there only by the tonic influence of the solids; now, as the least cause alters and changes their properties, it is subject there to an infinity of irregular motions. The least irritation makes it recede, advance, deviate to the right, or the left, &c. In the ordinary state, it moves generally in an uniform manner from the arteries towards the veins; but at every instant it may find causes of irregular oscillations in its innumerable anastomoses; hence, as we have seen, the necessity of these anastomoses. These irregular oscillations in the motion of the blood in the capillary system, can be seen with a microscope. Haller, Spallanzani and others, whose experiments are too well known for me to relate them here, saw them a hundred times. They saw the globules advance, recede, move in many different directions in animals with red and cold blood, when they irritated the mesentery or any other transparent part. In animals with red and warm blood, in those even whose mesentery is almost as transparent as that of the frog, as in the guinea-pig, it has appeared to me infinitely more difficult to trace the motion of the blood in the capillaries.

It is easy to see that all the phenomena of inflammation, of different eruptions, of tumours, &c. are especially found-

ed upon this susceptibility of the blood, in the capillary system, to move in an infinite variety of directions, wherever irritation calls it.

From what has been said, it is evident that there are times when the blood passes with less rapidity through the capillary system, and there are others, when it moves more quickly. How then is the relation always preserved the same, between the arterial and the venous blood? It is in this way; the irregular oscillations hardly ever take place except in one part of the capillary system; in no case is the whole of it affected; thus if the blood moves more slowly in the cutaneous capillary system, its velocity is increased in the cellular, the muscular, &c.

This is in fact an invariable law in the vital forces, that if on the one hand they increase in energy, on the other, they diminish; we might say, that there was only a certain quantity in the animal economy, that this might be divided in different proportions, but it cannot be increased or diminished. This principle results so evidently from all the phenomena of the economy, that I think it unnecessary to support it by numerous proofs; now, taking this as incontrovertible, it is evident that one portion of the capillary system increasing its action, only at the expense of the others, the sum total of blood transmitted from the arteries to the veins remains always nearly the same. All the systems are then, in this respect, supporters of each other; if nothing passes by the capillaries of one, it is the same thing, provided the capillaries of another transmit double the amount of fluid that they do in an ordinary state.

Observe the blood in the cutaneous capillaries before the paroxysm of intermittent fevers; it recedes from these capillaries; all the surfaces that it reddened, become pale; the capillaries of the other systems supply the momentary defect of the action of these. Who knows if, in many cases where the skin becomes very red, when much blood en-

ters it, there is not in the other systems a paleness analogous to that of the skin during the cold fit of fever? I not only think this very probable, but I have no doubt of it. The external capillaries certainly contain more blood in summer, whilst those of the internal systems receive more in winter. There is then continual varieties in the mode of the passage of this fluid through the general capillary system; each system transmits by turns, more or less, according as it is affected.

When we see the glands, frequently in a short time pour out an enormous quantity of fluid, the serous, cutaneous, mucous exhalants, &c. furnish also much greater proportions than in a natural state, we are astonished that the circulation can at the same time continue with the same regularity; we are not less so undoubtedly, when we see on the contrary all the evacuations suppressed, and nothing goes out from the animal solids; now in all these cases, it is the capillary system, whose forces differently modified in the different parts, re-establishes the general equilibrium which would inevitably be lost, if the heart was the agent of impulse which pushed to the extremities the secreted and exhaled fluids, and transmitted the black blood to the veins.

Sometimes however a derangement almost universal takes place in the capillary system, especially on the exterior; this takes place in sudden changes of the air. Though the vital laws preside essentially over the capillary circulation, yet the degree of pressure of the surrounding air can modify it to a certain point; we have a proof of this in cupping glasses, or in any other means that produce suddenly a vacuum upon a part of the body; then the fluids pressed in the neighbourhood by the external air, and not compressed on the contrary at the place of the cupping glass, raise up and distend considerably thes kin. The sudden changes of the atmosphere produce upon the whole body, though in a less degree, the effect of a cup-

ping glass. If the air is rarefied, the whole external capillary system is more full; even the sub-cutaneous veins swell; a very considerable part of the blood experiences then a derangement in its motion, between the two systems with red and black blood. The harmony, the correspondence of these two systems is disturbed; hence the uneasiness, the sense of weight, &c. of which we are instantly relieved by a sudden change of the atmosphere.

The evacuation of the blood also establishes differences, though less, in the capillary system. Bleeding is of two kinds; one lessens the blood of the circulation of the great trunks; and then it is sometimes red, as in arteriotomy; but most often it is the black, that is drawn off; the other takes blood from the capillary circulation; this is done by leeches, cupping, &c. Each produces a different change in the course of the blood. Physicians formerly were desirous of knowing from which vein they ought to bleed. I think it is much more important to know when we should by bleeding, act upon the general circulation, and when upon the capillary. In many local congestions, I do not think that you can diminish the quantity of blood in a part of the capillary system, by diminishing the mass of this fluid in the great trunks; you might take a quarter at least of the blood that there then was in the economy, if the part is irritated, the blood will still flow as much to this part. On the contrary, you may double by tranfusion, the mass of this fluid in an animal, local inflammations will not arise, because there must be a preliminary irritation before the blood flows towards, and enters a particular part of the capillary system.

The fluids differing from the blood which circulate in the capillary system, 1st. are evidently like it beyond the influence of the heart. 2d. The influence of the tonic powers presides over their motions. 3d. They are con-

sequently subject to irregular oscillations, according as the capillaries are differently affected.

We know not the nature of most of these fluids, because they cannot be subjected to our experiments. They are those that enter the ligaments, the tendons, the aponeuroses, the hair, the cartilages, the fibro-cartilages, a part of the cutaneous, mucous, serous surfaces, &c. They communicate with the blood from which they arise, by the capillary systems, they afterwards move in their own systems. In most of the organs in which they exist alone, as in those called white, they are very slow in their motion, because the sensibility of these organs is obscure and dull. Thus different tumours, to the formation of which they contribute, have, as we shall see, almost always a chronic progress.

There are often in the animal economy those tumours, that are commonly called lymphatic, though we are wholly ignorant of the fluids that form them. They are found especially in the neighbourhood of the articulations; but sometimes only the cartilages, the cellular texture, the bones, &c. are the seat of these white tumours; it is important to ascertain the characters that distinguish them from the tumours in which the blood especially enters.

Phenomena of the Alteration of the Fluids in the Capillary System.

We have just treated of the phenomena of the motion of the fluids in the general capillary system; let us now speak of the changes which they undergo there in their nature.

The blood exhibits a remarkable phenomenon in the general capillary system; from red, which it was in the arteries, it becomes black. How does this take place? It evidently can happen only in two ways, viz. either by the addition or subtraction of some principles. Is it charged with carbon and hydrogen? Does it deposit only

oxygen in the organs? Are these two causes united to give it its blackness? I think that it will always be difficult to decide upon these questions, which do not appear to me to be capable of any positive experiment. However, when we see the arterial blood furnish all the organs with the materials of their secretion, nutrition and exhalation, it is to be presumed that it leaves in these organs, rather than takes from them, the principle of its colour.

Sometimes the red blood passes through the capillary system, without losing its colour; for example, when the blood has flowed for a long time black from a vein, we sometimes see it come out red, or nearly so, just before it ceases to flow. In opening the renal vein, I have two or three times made this observation, which has, I think, been noticed by some authors.

The blood becomes more or less black in the general capillary system. If you have observed bleedings, you have undoubtedly seen in diseases innumerable varieties in the colour of the blood that comes from the vein. Has this fluid a different blackness in each part of the capillary system? It has appeared to me that the difference is not very great in this respect. I have frequently had occasion to open the renal, saphena, jugular veins, &c. the blood has appeared to me to be everywhere of nearly the same colour. I wished to see if the blood returning from an inflamed part was more or less black; I made then in the hind leg of a dog a number of wounds near each other, and left them open to the air. At the end of three days, when the inflammation appeared to be greatest, I opened high up on the diseased and the sound limb, the saphena and the crural veins, in order to examine their blood comparatively; I could discover no sensible difference. I bled a man who had a whitlow with an inflammatory swelling of the whole hand, and the inferior part of the fore arm; the blood appeared of the same colour as usual. Yet, as the veins bring also the blood of

parts not inflamed, more minute researches must be made.

An object which deserves to be determined with precision, is this, viz. the cases in which, in general diseases, there is an alteration in the deep colour of the blood, and the symptoms which correspond with these alterations. At present we only know that it is more deep coloured in some cases and less so in others.

IX. *Of the Capillaries considered as the seat of the production of Heat.*

Every one knows the innumerable hypotheses that were made upon the production of animal heat by the mechanical physicians. Modern chemists, in showing the insufficiency of these theories, have substituted one that has not less difficulties. The lungs are considered by them as the place in which the caloric is extricated, and the arteries, a kind of tubes, that carry the heat to all parts of the body. The production of this great phenomenon belongs then wholly, according to them, to the pulmonary capillary system. I believe, on the contrary, and I have taught in my courses on physiology, that it is in the general capillary system that it has its seat.

I shall not stop to refute the hypothesis of the chemists. When we place on one side, all the phenomena of animal heat, and on the other, this hypothesis, it appears so inadequate to their explanation, that I think every methodical mind can do it without my assistance. These phenomena are the following:

1st. Every living and organized being, both animal and vegetable, has a temperature of its own. 2d. This temperature is nearly the same in all ages in animals. 3d. It is entirely independent of that of the atmosphere; it remains the same in a warm as in a colder medium. 4th. Caloric is often disengaged in health more abundantly in some parts than in others. 5th. In inflammation

there is evidently a more considerable extrication of it. 6th. The vital forces, especially the tonic power, have a very decided influence upon the extrication of caloric. 7th. Each organ has its own temperature, and it is from all these partial temperatures, that the general one arises. 8th. There is oftentimes an immediate connexion between the respiratory and circulatory phenomena, and those of the production of heat; the first increasing, the second increase also in proportion. At other times this relation does not exist.

If, below these phenomena, you place the theory of Lavoisier, Crawford, &c. I do not believe you can make it accord with them, and conceive how caloric, disengaged in the pulmonary capillary system can be spread, as they say, through the whole animal economy. By admitting on the contrary that this fluid is disengaged in the general capillary system, it is easily understood. But let us explain this way of understanding the production of animal heat.

The blood draws from two principal sources the substances that repair the losses it has sustained. These sources are, 1st, digestion; 2d, respiration; the first pours chyle into the blood, the other mixes it with different aerial principles. Sometimes cutaneous absorption introduces into it different substances. The mixture of the blood with the new substances it receives, constitutes sanguification. Now these new substances carry continually into this fluid, new caloric; for as all bodies are penetrated by it, there can hardly be an addition of a substance to the blood, without the addition of this principle. In sanguification, caloric combines then with the blood, but it is not in a free state; it becomes part of the fluid; it is one of its elements.

Thus charged with combined caloric, the blood arrives in the capillary system; there it gives it out, wherever it undergoes changes. It is in fact in this system that it

is changed into nutritive substance, into that of the secretions, exhalations, &c. All the functions in which this fluid changes its nature, in which certain principles are separated from it, to form certain substances destined especially to particular uses, necessarily disengage its caloric. I cannot say precisely how this happens, whether it is more in the internal alterations that the blood undergoes in furnishing nutrition, or in those destined to furnish secretion or exhalation. This only is the general principle, and exhibits three things; 1st, the entrance of caloric into the blood, with all the substances that repair its losses; 2d, the circulation in a combined state of the caloric newly entered; 3d, extrication of this combined fluid, to form free caloric by the changes and different alterations that the blood undergoes in the general capillary system, in forming the materials of the different functions.

The extrication of caloric is, then, a phenomenon exactly analogous to those of which the general capillary system is the seat. In nutrition, in fact, there is, 1st, a combination of new foreign substances with the blood; 2d, circulation in the great vessels of these substances combined; 3d, separation of the nutritive substance to enter the organs. So also the elements of the secreted fluids combine, then circulate combined, then leave the blood to be thrown out. So, in fine, every exhaled fluid combines, circulates, and is then separated from the blood.

From this it is evident that, 1st, the entrance of foreign substances into the blood by respiration, by digestion or even cutaneous absorption; 2d, the combination of these substances with the blood in sanguification; 3d, their circulation in the arterial system, are three general phenomena common to secretions, exhalations, nutrition, and calorification, if I may be allowed the term; for the production of heat is a function and not a property; hence why I think the word caloricity does not express it.

The caloric arrives, then, in the capillary system combined with the matter of secretions, exhalations, and nutrition. The blood is the common fluid that results from all these combinations. In the general capillary system each part is separated; the caloric to be distributed over the whole body and afterwards pass out; the fluids of the secretions go out by the glands; those of exhalations escape from their respective surfaces; those of nutrition remain in the organs.

It seems to me, that the explanation which exhibits nature always pursuing an uniform course in her operations, drawing the same results from the same principles, has a greater degree of probability than that which shows her separating, as it were, this phenomenon from all the others, in the way which she produces it.

The manner in which caloric enters the body, is of no consequence. Vegetables that have no lungs, but only air tubes and absorbents, and fishes that have branchiæ, have an independent temperature. That heat may be produced, it is sufficient that foreign substances are continually assimilated to the fluids of organized bodies, and that after this assimilation, these fluids, whether they are blood, as in animals with red blood, either warm or cold, or whether they are of a different nature, as in those with white fluids and in plants, it is sufficient, I say, that the fluids undergo different transformations in the capillary system.

Respiration combines more caloric with the blood; there is consequently a greater disengagement of this principle in animals who breathe by lungs, than in others; and even in the first, the greater the lungs, the greater is the quantity of caloric disengaged; as is proved by comparing birds, quadrupeds, the cetaceous tribe among fishes, &c. But these varieties are certainly only in relation to the degree of temperature; hence there are animals with cold blood, and those with warm. The gene-

ral phenomena of the disengagement of heat remain always the same in animals with lungs, in those without them, and in plants.

From these principles, it is easy to understand most of the phenomena of animal heat.

The disengagement of caloric is always subordinate to the state of the vital forces. As the tone of a part is greater or less, it is more or less warm. This dependance of the heat upon the state of the forces of the part, is a fact, that is proved by all diseases and all the phenomena of health; it is as true with regard to heat, as it is with regard to the exhalations and the secretions. The greater afflux of blood to an inflamed part and the greater disengagement of caloric, the increase of this disengagement in the womb and the nose, and menstruation and the active nasal hemorrhages, &c. the heat of the chest and active pulmonary hemorrhages, &c. are the effects of the same cause, viz. the increase of the vital forces of the part. In general, whenever the tone is much increased, the heat increases also; hence why there is a greater disengagement of it in almost all active sweats, hemorrhages, and even secretions; whilst this fluid is not superabundant in sweats, hemorrhages, or secretions that are called passive, whatever may be the quantity of fluid separated from the blood by them.

Each system has its own degree of heat. There is certainly less caloric given off in the hair, the nails, and the epidermis, than in the other systems. The white organs, as the tendons, the aponeuroses, the ligaments, the cartilages, &c. have probably less than the muscles. Examine the claws of birds, in which there are only these white parts; they are not so warm as the rest of the body.

The difference of the heat of each system situated in the interior has not yet been analyzed; I am persuaded that if it was done with precision, by insulating those

which can be, so that they might communicate by the vessels, we should observe that each separates a different quantity of caloric, and that consequently there are as many distinct temperatures in the general temperature, as there are organized systems.

I am convinced that the ligaments, the cartilages, &c. approximate in this respect the organs of animals with cold blood, and that if man was composed of organs analogous to those, his temperature would be much inferior to what it naturally is. The systems which disengage more caloric communicate it to those that disengage less. If the hair was in the middle of the body, it would be as warm as the neighbouring parts, though its temperature would be independent; it is now always inferior to that of the body, because it is insulated. Each system has then its peculiar mode of heat, as each has its peculiar mode of secretion, each exhalant surface its peculiar mode of exhalation, each texture its peculiar mode of nutrition; and all this depends immediately on the modifications that the vital properties have in each part.

It is in consequence of this peculiarity of heat in each system, that each gives a different sensation in inflammation. Compare the sharp and biting heat of erysipelas with that of phlegmon; certain dull, obscure heats, the forerunners of organic affections, with the acute heats of different inflammations; apply the hand to the skin in different fevers, you will see that each is almost marked by a particular kind of heat. Animal bodies alone exhibit these varieties of nature in heat; minerals have only varieties in degree.

We understand from the principles explained above, not only the local alterations of heat, but also the general derangement that takes place in its disengagement, from the effect of diseases, whether this disengagement is increased, diminished, or affected with irregularities, as in certain ataxic fevers, in phthisis, when the palms of the

hands and the face are warmer in some cases, &c. Who does not know that oftentimes when the extremities are frozen, the patient feels an extraordinary internal heat? It is sufficient that the forces of the capillary system be differently modified, that the heat may be so also.

Observe, in fact, that the alterations of heat in diseases are as frequent as those of the exhalations and secretions, and that they always present, like the first, a previous derangement in the vital forces. If chemists apply their theories to these morbid changes of heat, instead of considering them as a necessary consequence of the state in which the vital forces are then found, they will necessarily find in them an insurmountable obstacle.

When we run swiftly, when the blood is violently agitated in the paroxysm of fever, more caloric is disengaged than at any other time. Does this prove that it is the general circulation which contributes to the disengagement of caloric, and that it takes place in the great vessels? No more than a copious sweat proves that the heart drives it out. Strongly excited by the shock of the red blood which is suddenly increased, the capillary and exhalant systems are compelled to increase their action; now a double effect is the result; 1st, greater disengagement of caloric; 2d, increased exhalation.

If the heat is increased when respiration is hurried, it appears to depend only on this, that the latter is hardly ever accelerated, without the circulation being so too. This is so true, that if you make for a long time rapidly successive inspirations and expirations, the heat will not increase. Besides, why should the heat actually increase by the hurry of respiration? Undoubtedly because more air entering in a given time, the lungs would absorb more oxygen, and consequently, according to the opinions of the chemists, more caloric would be disengaged. But let them present more or less of this principle to the blood, it absorbs the same quantity. In ordinary inspira-

tion the air contains much more than can pass into this fluid. When an animal is made to breathe it pure, the blood does not become more red, because the same quantity always enters it. So you may in vain put into the alimentary passages four times more nutritive substance than common, no more chyle will be formed, the lacteals will absorb no more; there will only be more excrements, or vomiting will take place.

The state of respiration has no influence then upon the actual heat of the body; it only contributes to it by constantly introducing a greater or less quantity of combined caloric. It is thus that animals which respire the most, have habitually the most caloric.

How can an animal, breathing a very cold air, eating aliments almost deprived of caloric, &c. in northern latitudes, have as much heat as in hot climates? It is not the free caloric contained in the parts, but the combined, which, being introduced into the blood with the foreign substances, furnishes the materials of that which is disengaged in the general capillary system. Now the combined caloric is absolutely independent of temperature. As much fire is elicited from the same stone by the steel, in the coldest as in the warmest countries.

All the caloric that is combined with the red blood is not disengaged whilst this fluid is passing through the general capillary system; there remains some of it still combined with the black blood. Hence why in the first moments of asphyxia, before death has taken place, though in consequence of the interruption of respiration, all the blood that comes through the arteries to the capillaries is black, the heat continues to be generated for some time. When the contact of the black blood has even interrupted all the great functions, those of the brain, of the muscles, the heart, the lungs, &c. it appears that the black blood then undergoes for some time, a kind of oscillation in the capillary system, by which it disengages a little caloric.

Hence, why those who have died of asphyxia produced by charcoal, or hanging, animals killed in vacuo, apoplectics, &c. preserve their heat a long time after death, as all physicians have observed.

This phenomenon is not however peculiar to the case of which we are treating. In opening dead bodies at the Hotel Dieu, I have observed that the time in which they lost their animal heat was very variable; that a body continues warm a greater or less time, especially among those who have died suddenly of an acute affection, in the paroxysm of an ataxic fever, for example, or by a fall, for those who die of a chronic disease, lose almost immediately their caloric. The difference in the first is often three, four, or even six hours. This phenomenon arises from the fact, that whenever death is sudden it interrupts only the great functions; the tonic action of the parts continues for a greater or less time after. Now this action disengages a little caloric from the blood that is in the general system. Thus in violent deaths, absorption continues some time after death; thus the muscles still contract; thus perhaps the glands, take up for some hours, from the blood that remains in the capillary system, the materials proper for their secretion.

This inequality in the heat of dead bodies can only arise from the cause I have named; for when the disengagement of caloric has ceased in the body, that which remains in it becomes in equilibrium with that of the external air, according to the general laws of this equilibrium. Now these laws being uniform, their effect would be the same in every case. Hence then the phenomena related above, are evidently incompatible with any other theory than that which supposes the caloric to be disengaged in the general capillary system.

Sympathy has, as we know, the greatest influence upon heat. According as this or that part is affected, there is disengaged in others more or less of their fluid. An icy

coldness often takes place in syncope. Ulcerations of the lungs produce a burning in the palms of the hands. In other affections, the head seems to be the seat of the greatest heat. In a fever frequently the patient is hot in one place and cold in another. How does all this happen? in this way; the affected organ acts sympathetically on the tonic forces of the part; these being raised, more caloric than usual is disengaged; it is precisely the same as in sympathetic secretions or exhalations. Whether the vital forces are raised by a stimulus directly applied, or by the sympathetic influence they receive, the effect that results from it is exactly the same.

It is necessary to distinguish this sympathetic increase of heat, from those that are produced by an aberration of perception, as when we think we are very hot or cold in a part, or experience even a sensation exactly analogous to those that are natural, though the part to which we refer this sensation may be in its natural state, there being neither more or less caloric disengaged in it. It is as when we think we feel pain in the amputated extremity of a limb. It is an aberration of perception; it is truly a sympathy of animal sensibility, whereas the preceding is a sympathy of insensible organic contractility or tone. It is this last property that is affected; the disengagement of caloric is a consequence; it takes place as usual, like the perception that indicates its presence. Another person's hand applied on the part, feels nothing new in the first case, of which I shall say more in the following systems; it experiences a warmer sensation in this. So if the effect of the sympathetic influence is to diminish the tonic forces, there will be a less local disengagement of this fluid, which will be equally perceptible to the individual and to any other person who applies his hand to the part. Diseases continually furnish us with examples of these phenomena in relation to heat, and no other theory than the one now given would be able to explain them.

There is a phenomenon that is as difficult to be well understood by this theory as any other; it is the faculty animals have of resisting external heat. Every inert body is of the same temperature as the medium which surrounds it. Every organized body on the contrary repels the caloric that tends to raise it to a higher temperature than its own. Perhaps this belongs to the laws of the propagation of caloric, of which we are ignorant.

It will be asked undoubtedly why in the ordinary state there is only disengaged a certain quantity of caloric, so as to produce an uniform temperature of a certain number of degrees of the thermometer. I answer that it is by the same cause that in the ordinary state the pulse beats nearly the same number of times in a minute, which makes common respiration consist of so many elevations and depressions of the ribs, &c. &c. It is one of those phenomena that belongs to the immutable order first established, and which it is impossible to explain. Only it appears that this immutable order depends upon the primitive type that has been impressed upon the vital forces, a type, which when nothing excites or diminishes them, produces always phenomena nearly uniform; but as a thousand causes make them vary, a thousand times the pulse, respiration, heat, &c. are capable of differing. I would observe however in regard to the last, that its variations are not so great as those of many of the other functions. Compare, for example, the ordinary quantity of secreted and exhaled fluids, with the increase that takes place under certain circumstances, the common state of the pulse with its exacerbations in many fevers, &c. you will see that between the natural and the morbid state there is often an enormous difference. The heat on the contrary, is never raised but a few degrees above the temperature of the body. When there appears by touching the parts, to be a great difference, the thermometer proves that it is in reality trifling.

I would remark, in concluding this article, that I have not sought to ascertain how the caloric is disengaged in the capillary system, what portion escapes, in what relation it is with the red and the black blood, &c.; none of these can be determined by experiment. Let us be content in our theories with establishing general principles, especially analogies between functions that are known, and those which we attempt to explain, let us attempt merely to offer some general views; but let us never hazard precise explanations. Some have endeavoured lately to determine accurately what quantity of oxygen is absorbed, what quantity goes to produce the water of respiration, what quantity of carbonic acid gas is formed, how much caloric is disengaged, &c. This precision would be advantageous if it could be attained; but no phenomenon in the living economy will admit of it, in the explanations which it occasions. Chemists and natural philosophers accustomed to study the phenomena over which the physical forces preside, have carried their spirit of calculation into the theories they have formed for those which the vital laws govern. But this should not be so. In organized bodies, the spirit of the theories should be wholly different from the spirit of the theories applied to the physical sciences. It is necessary in these last that every phenomenon should be accurately explained; that, for example, in hydraulics, all the portions of the fluids should be calculated in their motions; that, in chemistry, we should know the precise proportion and amount of each of the elements that are combined in the changes that bodies undergo.

On the contrary, every physiological explanation should give only general views, approximations; it ought to be vague, if I may use the term. Every calculation, every examination of the proportions of the fluids with each other, all precise language should be banished from it, because we yet know so little of the vital laws, they are

subject to so many variations, that what is true at the moment we study a fact, ceases to be so the next, and the essence of the phenomena always escapes us; their general results only, and the comparison of these results with each other, should occupy us.

ARTICLE SECOND.

PULMONARY CAPILLARY SYSTEM.

I CALL by this name the assemblage of the fine and delicate ramifications, which serve for the termination of the black blood and the origin of the red, which consequently finish the pulmonary artery and give origin to the pulmonary veins. The capillaries between the bronchial arteries and veins have nothing to do with them, they have no communication, and evidently belong to the general capillary system.

I. *Relation of the two Capillary Systems, Pulmonary and General.*

In comparing the preceding system with this, it is difficult to understand how they can exactly correspond, how the pulmonary can transmit not only all that passes through the general, but also all the lymph that returns from the serous surfaces and the cellular cavities, all the chyle which enters by digestion, &c. &c.

It seems impossible at first view, that in the balance of the circulation, these capillaries can, constantly and regularly, keep in equilibrium with those of the rest of the body. By reflecting a little, however, upon the phenomena of this function, we see that the discordance is only apparent.

Though the general capillary system is everywhere spread out, yet the portion in which blood circulates is much more limited than at first appears. There is a great part of the vessels of this system, in which fluids differing from the blood move and oscillate in different directions. Then, where the blood especially enters, as in the muscles, the mucous surfaces, &c. a considerable portion of this fluid, its colouring matter particularly, is in a combined state, and not in a state of circulation. If we cut a muscle transversely in a living animal, inspection proves clearly this phenomenon, which, joined to the preceding, diminishes immediately more than half the blood, which at first appears to move in the general capillary system.

Yet it is evident, that there remains much more of it constantly in this system than in the pulmonary; to be convinced of this, it is only necessary to cut the lungs of a living animal. From this it is clear, that if the heart presided over the motion of the blood in the general system, and that consequently all that is contained in it was driven into the veins at each pulsation, the pulmonary capillaries would be insufficient to transmit it; but there goes out only a certain quantity, proportioned to what the lungs can receive. It is nearly the same as when the veins are much dilated, and consequently contain much blood; no more arrives at the heart, because, as I have said, the velocity is then in the inverse ratio of the capacity.

Besides, many causes continually divert the blood of the general capillary system from the direction which carries it from the arteries to the veins; these causes are especially the exhalations, secretions, and nutrition. This capillary system is, as I have observed, a common reservoir, whence the blood is carried into different and even opposite directions, on one part in the direction of the veins, on another in that of the exhalants, on another in

that of the excretories, on another, in fine, in that of the nutritive vessels. On the contrary, in the pulmonary capillary system, there is but a single impulse, and a single direction; it is that which carries the blood from the artery to the pulmonary veins, which nothing draws off in its course; for in passing from the black to the red, this fluid serves no other function; it has no vessels, but the pulmonary veins, towards which its motion is directed. There is, then, this great difference in the blood of the pulmonary capillaries, and that of all the other parts, viz. that the first is moved only in one direction, that all which arrives in the lungs goes immediately in this direction; whereas the second has four or five different directions. Hence this last necessarily oscillates and varies in its motions, according as it is called more or less powerfully by the exhalants, the excretories, the nourishing vessels, or the veins; whereas the other, having but one way to escape, follows it constantly and uniformly. Let us not be astonished, then, at the disproportion there is in the capacity of the two capillary systems.

The proximity and distance of the heart are also a real cause that tends to establish the equilibrium between the two systems. We have seen, in fact, that each contraction of the left ventricle impresses a sudden motion upon the whole mass of blood contained in the arteries, and at the instant that this mass increases on one side, it is diminished on the other by the quantity that is sent to the capillaries of the whole body; so that the arterial motion is not progressive, but sudden and instantaneous, so that at the same time the column of aortic blood increases towards the heart, it diminishes in its remote ramifications, and the fluid driven from the heart at each contraction, does not arrive at the capillaries until after many contractions, since that which goes from this organ cannot arrive at these vessels until all which is before it has reached them. The same phenomenon precisely

takes place as it respects the black blood in the pulmonary artery. Then the longer the course, the longer is the time that is required for the blood to arrive at the capillaries, and consequently to pass through them; then the blood from the right ventricle would arrive much sooner at the left auricle, than that would at the right auricle which goes from the left ventricle; then, though in what we call the small circulation, the velocity is not greater, the space passed over being less, the time employed to go over it is also less; then, the excess of the fluid contained in the divisions of the aorta, in the general capillary system, and in the general veins, over that contained in the pulmonary artery, veins and capillary system, is compensated by the time the second takes to go its course, which is short in comparison to that of the first.

Hence we see, why in animals in whom the lungs, as to their circulation, are in opposition to the rest of the body, nature has constantly placed this organ at the side of the heart. If one of these organs was at the head, and the other at the bottom of the pelvis, the harmony would be inevitably interrupted.

II. *Remarks upon the Circulation of the Pulmonary Capillaries.*

Since the blood of all the parts constantly goes through the lungs, it is evident that an injury of the functions of this viscus would be felt in all the parts. The phenomena of asphyxia prove that this in fact takes place. It is in this way that the lungs are immediately connected with life, and hence the ancient physicians placed its functions among those which they called vital.

We understand also why pulmonary inflammations have so peculiar a character; why they are distinguished from others by many phenomena. No internal organ is more often inflamed than the lungs. If experience did not prove this at the bed-side of the patient, the exami-

nation of dead bodies would be sufficient to convince us of it. We find in fact around the lungs, very often traces of old inflammations, particularly adhesions of the pleura; a phenomenon so common, that I am confident that there are more dead bodies found with it, than there are without it. This is an essential difference of this membrane that distinguishes it from all analogous ones, a difference that arises from the proximity of the pleura to the organ that it covers. Different causes contribute to this very great frequency of pulmonary inflammations. 1st. The lungs are, among the internal organs, the most exposed to direct irritations, either by the air that constantly enters them and can irritate them, or by heterogeneous substances that it introduces, or especially by the changes of heat and cold that it occasions. 2d. These organs are connected by the most numerous sympathies with the other systems, the cutaneous, for example; so that perhaps, as it respects inflammation, a suppression of transpiration has as much influence upon the lungs alone, as upon all the other organs together. It depends no doubt upon this that the lungs correspond with all the others by their capillaries.

When the lungs are inflamed, is it the red blood of the bronchial artery that flows to the irritated place, or the black blood of the pulmonary artery? I think that it is difficult to decide this question by experiment; but examination after death appears to prove that the second performs an important part in it. In fact, this viscus is often crowded so suddenly, that we can hardly believe that the first would be able to furnish the blood. Sometimes, though it is not always the case, we can trace as it were, the progress of this crowding by percussion, which is infinitely less sonorous in the evening than the morning. There died a short time since a patient under my care in the hospital, in whom this difference was perceptible from hour to hour. The progress is much less rapid, no

doubt, in the greatest number of cases; but in those the black blood has undoubtedly contributed to the crowding of the lungs.

No organ in the animal economy acquires by inflammation, so great a size in so short a time, and such excessive weight, as the lungs. All who open dead bodies know this. Observe the lungs of one dead of pneumonia; cut them, and you would say at first that they were solid: they often look like liver, they exhibit the appearance of such a heavy mass; but macerate them and soon the whole will escape in fluids. Now examine comparatively the skin, the stomach, the liver, the kidnies, &c. when they have been the seat of acute inflammation, that has destroyed the patient; they have nothing approaching to this enormous increase of fluid, which is seen in the substance of inflamed lungs. Not only the cavity of the cells is full, but the organ is also much dilated. I have often had occasion to open those who have died of pneumonia, in whom one of the lungs was entirely sound; now, the disproportion of weight between it and the affected one, was incomparably greater than that between an inflamed kidney and a sound one.

This phenomenon evidently arises from the fact, that the lungs alone receive as much blood as the whole body, so that when an inflammation of this viscus interrupts the course of the fluids, a very great quantity of them can accumulate there in a given time. It is not however, properly speaking, the blood that is found crowding the lungs in pneumonia; the fluid appears whitish when pressed out; we should say that it was a kind of pus. Much has been said of vomicæ after pneumonia; but they are extremely rare; there is almost always effusion in the lungs; the fluid is not collected in a sac.

In pulmonary inflammation, does the blood pass through vessels that do not ordinarily circulate it, as happens so evidently upon the serous surfaces, or conjunctiva, &c.

when inflamed? I do not think it does, for we do not know any vessels in the lungs, except the sanguineous. It appears evident that the blood or the other fluids are effused into the pulmonary texture, in which they are deposited by exhalation. There is no doubt that in some phlegmons, this fluid passes, as I shall say, into the cells of the cellular texture; now it appears that it happens here in the same way. By breaking or cutting inflamed lungs, we see clearly that its whole texture is crowded, and filled; whereas in examining an inflamed serous surface, we see that the blood is evidently contained in the capillaries.

It is a great mistake to try to represent inflammation as being everywhere the same, as exhibiting always the fluids, like their vessels, in the same state. Boerhaave for example thought, that there could be no inflammation without an *error loci*. There is according to the state of the parts, their structure, their vital properties, a thousand different modifications in the new anatomical order that this affection gives to the organs.

What constitutes the essence of inflammation is, 1st, the irritation of the inflamed part; 2d, the new modifications that its vital forces have taken in consequence of that irritation; 3d, the consequent stagnation of the fluids around it. But in what manner the fluids are arrested; how they stop in the capillary system; how they are taken up by the exhalants; how they are poured out, in extravasations, &c.; these are different effects that arise from the different organization of the parts; but the principle is always the same, it is always the same disease. If we could analyze thoroughly the state of all the systems in inflammation, we should see perhaps, that there was a difference in the inflammation of each. Besides, the diversity of the symptoms that it exhibits, a diversity of which I have already spoken, proves that the state of the solids and the fluids are not the same.

How is it that the blood can pass through the lungs of phthisical patients, in whom this organ is reduced nearly one half? I would observe upon this subject, that the blood in the great vessels is diminished in proportion to the ulceration of the lungs. The diminution of this fluid is remarkable in many organic affections, but especially in these, as Portal has observed. If a phthisical patient in the last stage had as much blood, as before the disease, the circulation certainly could not go on, or at least there would be a constant reflux towards the right auricle. Who is ignorant of the small pulse, feeble though frequent, particularly towards night, in phthisis? Compare it with the pulse of an inflammatory fever, in which there is evidently plethora; you will see that they are really the two extremes.

I will make a general observation upon this subject, it is this, that when the forces are weakened in our organs, or life languishes in them, the blood is diminished almost continually in proportion; so that this fluid being considered in the capillary system, as the resistance opposed to the power of the small vessels, the proportion remains always the same between this power and this resistance. It is necessary that the whole should be in relation. If blood was transfused into a phthisical patient, he would die, because the forces of the solids would not correspond with the increase of action to which they would be forced.

The circulation of the pulmonary capillaries, is, like that of the others, under the influence of the tonic forces of the part, and not under that of the impulse of the heart. This impulse terminates at the extremity of the branches of the pulmonary artery. In inflammation then of the lungs, the blood is not mechanically arrested in this organ; then, when you bleed, it is not to diminish the *vis à tergo*. You might draw ten basins from the patient, but the lungs most commonly would not empty them-

selves; they would be less fatigued by the entrance of the blood; but that which was stagnant in the capillary system would still remain there. So long as there is a point of irritation, it will be, if we may so say, a magnet which will attract the blood, and completely change its direction; which was before from the artery to the veins, it will now be only towards the irritated point. Bleeding acts then, 1st, by diminishing the blood that enters the lungs, and consequently by lessening the fatigue of this diseased organ; 2d, by diminishing the irritation of the solid, which attracts the blood, and retains it around the irritated place.

The constant excitement that the air gives to the pulmonary capillary system is favourable to its circulation; but the blood can traverse this system without this excitement, as is proved by my experiments mentioned elsewhere.

III. *Alteration of the Blood in the Pulmonary Capillaries.*

There takes place here the reverse of what happens in the general capillaries; the fluid changes from black to red. We have already some data upon the causes of this phenomenon; but I think new experiments should be made before a thorough explanation can be given. This is so much the more necessary, because if we knew how the black blood becomes red, it would seem that we might know how the red becomes black.

I have stated the phenomena of this change of colour in my work upon Life and Death; it would be superfluous to repeat them. There will be found there also many details upon the circulation of the two capillary systems, which I shall not mention here.

IV. *Remarks upon the state of the Lungs in Dead Bodies.*

I will only corroborate here a remark already made in the same work, upon the extreme frequency of pulmonary congestions in the last moments of life. As the lungs alone receive the whole blood of the body; when their forces are weakened, the blood stagnates and accumulates in them; so that according to the state of their forces in the last moments, and the disease, these organs will be more or less heavy, and more or less full of blood. We hardly find them twice in the same state. All subjects that die in pain have these congestions. Thus compare the lungs of dead bodies in our dissecting rooms, with those of animals killed in slaughter-houses; they are entirely different. The organization is almost always concealed in the first by the fluids that crowd them. We cannot study this organization well except in subjects that have died of hemorrhage or syncope. In most others, it is impossible to distinguish any thing. Hence no doubt the reason that we know as yet so little of the intimate structure of this important viscus, as the description I shall give of it will, I hope, prove. I have shown elsewhere how we can at will accumulate a greater or less quantity of blood in the lungs of an animal, by the way in which we kill him.

No other organ in the economy exhibits these extreme varieties of congestion at the moment of death, in so evident a manner at least, because no one is a centre of circulation, like the lungs; the liver even is not an exception, as I have observed. In this respect, those who open dead bodies, and examine the state of the lungs, should carefully distinguish the congestion that arises from the disease, from that which may be perhaps the effect of the interruption of the circulation in the last moments. I suppose two affections of the chest exactly similar in their

nature, duration and the two subjects they attack; that syncope terminates the life of one of them; that that of the other is closed after long distress, in which there is what is called the rattles; the lungs of the second will certainly weigh much more than those of the first.

It is very probable that during life, the lungs are in very different degrees of congestion. We know that most chronic diseases of this organ occasion, when the patients take rather violent exercise, a sense of suffocation, oppression, &c. which appear to be owing only to the superabundance of blood, which, not being able to pass through this viscus as fast as it is sent there, is stopt, and checks the entrance and exit of the air.

It is only the diseases of the lungs and heart that are accompanied constantly with these oppressions, and sense of suffocation. This is seen in this last organ in aneurisms, sometimes in ossifications, &c.

EXHALANT SYSTEM.

EXHALATION and secretion are two functions, analogous in this, that both of them separate from the blood fluids differing from it, and pour them upon surfaces where they serve different uses. But the following are their differences.

1st. In exhalation, there is no intermediate organ between the arteries and the exhalants; a capillary net-work alone separates them; whilst on the contrary there is always an intermediate organ between the excretories and the arteries; it is in this organ that the capillaries are found, in which the second begin and the first terminate. 2d. The organized machines which elaborate the secreted fluids are then much more complicated than those which separate the exhaled fluids. Thus the bile, the urine, the saliva, &c. differ on the one hand essentially from the blood, and are on the other much compounded; whilst the serum, &c. closely resembles some parts of the blood, and is but slightly compounded, containing but few elements. This double distinctive character of the two kinds of fluids appears to me to be very striking. 3d. The exhaled fluids are poured out by an infinity of small tubes separate from each other; the secreted fluids, on the contrary, are collected in one or more principal tubes that

pour them on the surface where they terminate. 4th. The exhaled fluids re-enter in great part into the circulation, after having been thrown out; the secreted fluids, on the contrary, appear to be especially destined to be rejected. 5th. Many parts receive the first fluids; they are deposited upon the serous, mucous, synovial and cutaneous surfaces, in the cellular texture and even in all the organs of nutrition. The mucous and cutaneous surfaces, the first especially, are the only ones upon which the others are poured out.

It follows from all these considerations, that the exhaled fluids, as the fat, the serum, the synovia, the marrow, &c. differ essentially from the secreted fluids, as the bile, the urine, the saliva, the mucous, prostate, spermatic, pancreatic fluids, &c. This difference appears to have struck a great number of authors; yet most of them have made use of the term secretion to express the separation of the exhaled fluids from the mass of blood. I think that there is much analogy between exhalation and secretion. In both, there is the capillary system, as I have said, between the vessel that brings and that which carries away; but the capillary system is certainly arranged very differently in a gland, from what it is in a serous surface; for example, wherever there is exhalation, there is certainly nothing but the capillary system; but where there is secretion, the secretory organ is too considerable not to admit of something more. Besides, by trusting to inspection, and without wishing to examine the intimate nature of the organs, it is evident that where there is secretion, there is a gland, and that this gland is wanting where there is exhalation.

ARTICLE FIRST.

GENERAL ARRANGEMENT OF THE EXHALANTS.

I. *Origin, course and termination.*

Authors have formed very different ideas concerning the exhalants. We know the decreasing vessels of Boerhaave, and the error loci for which his imagination created these vessels. Lately all the white vessels continuous with the arteries have been rejected, and in order to explain exhalation, recourse has been had only to inorganic pores in the arterial parietes, through which the fluids transude upon the organs. Frequent observation of similar transudations upon the dead body, as those of the bile through the gall-bladder, of the marrow through the osseous texture which it discolours, &c. is one of the great supports of this method of explaining the exhalant system. But we have already many times observed, that these phenomena never take place during life, when the organic sensibility of the parts refuses to produce them. Besides, exhalation is evidently subjected to the influence of the vital forces, since it varies continually in a part, according as the vital forces of the part themselves vary. Moreover, if the exhaled fluids escaped through inorganic pores, it would be necessary that not only the vascular parietes, but also those of the serous surfaces which receive these fluids, should be perforated with small holes; why then would not these fluids, of which these surfaces are the reservoirs, transude into the neighbouring cellular texture? Let us reject then every opinion that disregards anatomical observation, and let us endeavour by this observation to ascertain what the exhalants are.

It is undoubtedly difficult to form a precise idea of these vessels, their extreme tenuity constantly conceals them from us in a natural state. Yet by the aid of ex-

periments and accurate reasoning, it appears to me that we may come at some degree of accuracy.

We have seen that the existence of a capillary system terminating the arteries, is in the parts where exhalation takes place as in the others, a thing incontestably proved by experiment with injections, by inflammations which arise spontaneously, and by those that are produced at will; so that a serous, cutaneous surface, &c. on which nothing appears, is covered with an infinity of little vessels suddenly in the first case, and at the end of a longer or shorter time in the second.

If the injection is not pushed very far, it is confined to the capillary system; but if it succeeds, it pours from all parts upon the surface, where exhalation takes place in the ordinary state. This dew mechanically produced, evidently resembles that which the tonic force of the parts occasions during life; for, as I have said, if it was a transudation, there would be extravasation in the neighbouring textures, whereas nothing is filled from the syringe which propels the injection to the exhalants that pour it out, except the arteries, the capillaries and these exhalants. Besides, when there is active hemorrhage, the capillaries from which arise the exhalants that pour out the blood, are evidently more full of fluid than ordinary, as I have already remarked.

From these considerations and many others that will be explained hereafter in this system, I think that we may consider the exhalants as arising from the capillary system, by means of which they are continued with the arteries, which bring them the materials of exhalation.

But to say what is the length of these vessels, what their form, what course they run, is evidently impossible; it is here that the imaginary descriptions begin. We distinguish with difficulty their orifices. We see upon the skin many little pores that evidently form communications from within to without; but these pores transmit

not only the exhalants, but also the absorbents, the hair, &c. as we shall see in the dermoid system. 1st. The existence of the exhalants; 2d, their origin in the capillary system of the part where they are found; 3d, their termination upon different surfaces, are upon the whole all that is accurately known.

The mode of origin undoubtedly varies, but we do not know how it takes place. The exhalants are continued with their capillary net-work, in such a manner that we cannot say precisely where one finishes and the others begin. Hence why often in this work, in speaking of these small tubes, I suppose them to come immediately from the arteries, and forming the capillaries by their interlacing; this is evidently sufficient to understand what will be said hereafter.

II. *Division of the Exhalants.*

There are three classes of exhalants which I distinguish by the fluids or the substances they furnish.

The first class contains those that throw out the fluids not destined to enter the economy again; such are, 1st, the cutaneous exhalants that pour out the sweat; 2d, the mucous exhalants that furnish a part of the pulmonary perspiration, the greatest part being formed, as I shall say, by the dissolution of the mucous fluids of respiration, which yield perhaps the gastric, intestinal juices, &c.

In the second class are found the exhalants, that throw out fluids that remain for some time upon certain surfaces or in certain cells; and which afterwards taken up by absorption, re-enter the circulation through the lymphatics. These are, 1st, the serous exhalants which deposit upon their respective surfaces the serum which lubricates the membranes and facilitates the motions of the organs they cover; 2d, the cellular exhalants which pour out into the cells, on the one part serum, on the other fat; 3d, the medullary exhalants which carry into the middle of the bones

the juices of the same name; 4th, the synovial exhalants which deposit the synovia, either upon the articulations, or in the tendinous grooves.

The third class contains the exhalants that carry to all the organs the nutritive substance that repairs them, and which is afterwards taken up by absorption, to be replaced by new substances.

I adopt in my course of physiology the division I have just pointed out, to explain the different exhalations, of which the last evidently leads me to speak of nutrition, a function which is the general end of those that form organic life. We can represent in the following table, all the different exhalations; it presents the assemblage of the organs that execute them.

EXHALANTS.	1st. exterior, open upon the systems,	1st. Dermoid.	
		2d. Mucous.	
	2d. interior, open upon the systems,	1st. Serous.	
		2d. Cellular, where they pour out,	1st. Serum.
			2d. Fat.
		3d. Medullary.	1st. of the short, flat bones, and the extremities of the long ones.
			2d. of the middle of the long bones.
		4th. Synovial.	1st. of the articulations.
			2d. of the tendons.
	3d. nutritive.	Each organized texture has its own exhalants.	

This is an accurate table of all the fluids that go out of the blood, without the intervention of the glands, and by the way of exhalation. The two first classes have vessels, as is accurately proved by experiment, observation and even inspection. As to the nutritive exhalants, there is no doubt but that new substances are continually carried to the organs to repair them; now it is necessary that these substances should have vessels; these vessels certainly cannot draw what they deposit in them, except from the capillary system in which they terminate. If

injections or other means do not accurately prove the existence of these exhalants, it seems to me that this reasoning forces us to admit them.

Physiologists had not hitherto collected together all the exhalations; each was explained in treating of the system where it was found. I have thus given reflections upon each in the exposition of the different textures; the arrangement of the general anatomy required it; but in works or in lectures on physiology, they ought evidently to be presented under the same point of view as absorptions.

III. *Difference of the Exhalations.*

Though we know not what is the structure of the exhalants, yet we cannot doubt but that this structure differs remarkably in the different systems. Observe in fact that these vessels enter, as it were, like elements into the textures they compose, and that consequently they must necessarily partake of the different and distinctive characters which these textures exhibit.

It is to this difference that we must refer without doubt what we see in injections. They go out, if they are fine, by the mucous, serous and even cellular exhalants; but those which furnish the synovia, transmit them with much more difficulty; it is the same in the capillary system; whilst the serous surfaces in this system are filled with great ease, and blackened by injections, as it were at will, the synovial surfaces are penetrated with much more difficulty.

ARTICLE SECOND.

PROPERTIES, FUNCTIONS, AND DEVELOPMENT OF THE EXHALANT SYSTEM.

I. *Properties.*

The vessels of the exhalant system are too delicate to allow us to analyze their properties of texture. Do they enlarge when the red globules enter them? I am wholly ignorant. Haller, who admitted that there were exhalants, thought that white fluids alone entered them, because their diameter was disproportioned to that of the red globules. This opinion is also that of the school of Boerhaave. Who has ever measured comparatively the respective diameters of the vessels and the particles of the fluids? All such expressions, as fine fluids, coarse fluids, &c. which are still used by many physicians, have originated from this theory and are still used, though the theory itself has been admitted to be false. I have said twenty times, and I again repeat it, that the only cause which prevents the red globules from passing into vessels with white fluids, is the want of relation between the nature of the fluid and the sensibility of the organ.

The properties of animal life have evidently no connexion with the exhalants. Of those of organic life, they have in the highest degree those of organic sensibility and the corresponding insensible contractility; it is upon these that all their functions depend.

Characters of the Vital Properties.

Though organic sensibility is everywhere given to the exhalants, it varies however remarkably in each system; that of the mucous exhalants is not the same as that of the serous. In general the exhalants entering as it were like elements into the texture of each system, partake completely of the organic properties of that system; or rather

their properties are the same. Hence, 1st, why each separates the fluid that is peculiar to it; why consequently, when much water is introduced into the circulation by drinking, the cutaneous exhalants, and never the serous, appropriate it to themselves, and transmit it out of the blood; when we run much and a general agitation is consequently given by the heart to the mass of blood in circulation, the cutaneous exhalants, being more powerfully excited by this impression than the serous, the synovial, &c. separate more sweat; 2d, why the serous do not pour out fat, the medullary serum, &c. though the mass of blood that enters the capillaries that are continuous with these exhalants, is everywhere the same; 3d, why when the exhalants pour out fluids that they are not accustomed to, or when their natural fluids are altered, these fluids differ essentially from each other; why, for example, after inflammation, it is only upon the serous surfaces that we see a milky serum; why nothing resembling pus flows from the inflamed medullary membrane; why the fluids, the result of the inflammation of the synovial membranes, are very different from those that the serous surfaces produce, &c.; 4th, why certain exhalants have a much greater tendency than others to admit blood and pour it out upon their respective surfaces, of which we see an example in the mucous exhalants, which are so disposed to suffer this fluid to pass, that a thousand circumstances occasion hemorrhages from them; 5th, why among the mucous exhalants themselves, some have a much greater tendency than other to permit the blood to pass, &c. &c.

All these phenomena are evidently derived from the particular modifications that distinguish the organic sensibility and contractility in each kind of exhalants.

II. *Of Natural Exhalations.*

What I have said will enable us to explain how exhalation is effected. It is by the same principle as that to

which we have before referred; it is that which will serve for the explanation of secretions, absorptions, &c. There is between the elements which form each exhaled fluid and the organic sensibility of each kind of exhalants, such a relation, that these elements alone can be admitted by the vessels which reject the others, so long as there is no change in their kind of sensibility. The general capillary system appears to be the reservoir, in which, as I have said, the blood is elaborated; it is there that the red blood becomes black; it is there at the same time that its different elements are separated, combine anew, and during these changes disengage caloric. It is after these changes, these different transformations, that each exhalant takes, chooses as it were the portions with which its sensibility is in relation, and leaves the others.

It follows hence as a very simple consequence, that whenever the organic sensibility of the system in which exhalation takes place is altered in any manner, exhalation should also immediately vary; and this in fact always happens. There is never any derangement in the exhalations, without a preceding one in the sensibility of the exhalants. Take for example the different injuries of transpiration; you will see that cold, heat, dryness, moisture, frictions, &c. always exert their influence upon the cutaneous sensibility, and that the derangements of the exhalation are consequent to them.

The organic sensibility of the exhalants, like that of every other part, may be disordered in different ways, 1st, by a direct stimulant, as when cold contracts the skin, when a very cold fluid acts upon the stomach, &c.; 2d, by sympathies, as when the acute affection of the fibrous and muscular organs produces sweat in rheumatism; 3d, oftentimes without our being able to say how, a derangement takes place in the vital forces of a part; of this inflammation presents frequent examples. I do not allude here to that which takes place from the contiguity of organs, &c. &c.

It follows from this, that when exhalation is preternaturally increased or diminished, the sensibility of the exhalants is always modified in one of the three preceding ways.

Now if we reflect upon the different kinds of exhalants, we shall see that there are no others except the cutaneous and the mucous which are exposed to the immediate application of stimuli, since they alone are in relation with external bodies. Besides the two modes of alteration of sensibility that they share with others, they have moreover this. It is not then astonishing, that their exhalations, especially the cutaneous, exhibit such numerous varieties, that the skin is continually found varying between the greatest dryness and the most copious sweat.

The sympathetic exhalations are extremely numerous. I shall not give examples of them here; many may be found in the sympathies of the dermoid, serous, mucous systems, &c. I would only observe that authors have not sufficiently distinguished this kind of exhalations from the others; nor has sufficient attention been paid to sympathetic secretions.

The exhalations are never all increased or diminished at the same time; I except however the state of excitement at the commencement of some fevers, when all are suppressed. In every other case, when one fluid is abundantly poured out, the others are diminished; thus the skin is dry in dropsies. There is sweating in the first stages of phthisis pulmonalis; but when in the latter, dropsical effusions are considerable, sweating ceases.

I have moreover divided into two classes the causes of increased exhalations. 1st, One of these proves an increase of life; 2d, the other, a real diminution of the vital forces; hence active and passive exhalations. How can the same phenomenon arise from two causes exactly opposite? It is difficult to determine precisely; but so many phenomena prove this distinction of exhalations as

well as secretions, that we cannot refuse to admit it. It is important to recollect this in the following article.

III. *Of Preternatural Exhalations.*

I call by this name those, in which the exhalants pour out a fluid different from that which is natural to them. The first which offers is that of the blood.

Sanguineous Exhalation.

The blood frequently passes off by the exhalants instead of their own fluids; hence arise hemorrhages very different from those that take place from rupture. I shall examine these hemorrhages in each kind of exhalants.

Hemorrhage of the Excrementitious Exhalants.

The vulgar expression which is sometimes used, to sweat blood and water, &c. indicates that under certain circumstances, though they are very rare, the cutaneous exhalants give passage to the blood. Haller has collected a number of instances of it, that may be found in his work. The first year that I came to Paris, I saw constantly with Desault, a woman with a cancer of the womb, who had at certain periods sweats that stained her clothes as much as is ordinarily done by the catamenia. This woman had had frequent hemorrhages before the beginning of her disease. After these sweats commenced, they had continued but were more rare. I regret that I neglected to collect the particulars of this singular fact.

No exhalants pour out blood more frequently than the mucous; so that hemorrhages are an affection almost characteristic of the mucous surfaces, in which they have different names, according to the portion of them that are attacked. It is not my object to present here the phenomena of these hemorrhages; I only wish to prove that they are an exhalation.

1st. I have very often opened subjects that have died during a hemorrhage; I have had occasion to examine with this view the bronchial, gastric, intestinal and uterine surfaces; I have never seen the least mark of erosion, notwithstanding the precaution of carefully washing the surfaces, of letting them macerate and even examining them with a glass. 2d. The following experiment uniformly succeeds upon the wombs of women who have died during menstruation, and often even at other times; by pressing them, there issues from the mucous surface a greater or less number of little bloody drops, which evidently correspond with vascular extremities, and being wiped off, no erosion can be seen. 3d. The analogy of all the other open surfaces that pour out blood, and which evidently do it by their exhalants, is a proof that the same phenomenon has the same seat in the mucous surfaces. 4th. The womb would be only a mass of cicatrices in females of advanced age, if there had been a rupture in it in menstruation. 5th. In active hemorrhages, in which there is evidently a congestion of blood previous to its escape, we can conceive, to a certain degree of the rupture of the small vessels; but in passive hemorrhages, in those in which the organic sensibility being annihilated, seems to allow of a simple transudation through the exhalants, how can we conceive of these ruptures? 6th. We understand with difficulty how an evacuation, which is often produced with an extreme rapidity, which ceases in one place and immediately appears in another, which is subjected to all the sympathetic influences, we understand, I say, with difficulty how it can happen from rupture. 7th. Observe menstruation, furnishing sometimes for one moment blood, and not giving it the next, renewing twenty or thirty times a day, in certain affections, these alterations of flowing and ceasing to flow; it would be necessary then, that at each time the wounds should open and be cicatrized. 8th. Besides,

compare hemorrhages evidently produced by rupture upon the mucous surfaces, such as those, which in wounds of the head, take place from the nostrils, the ears, &c.; those, which by a fall upon the rectum, sometimes happen from the bladder; those which, in too great efforts in coughing, arise upon the bronchial surface; those of which the stomach is the seat from the action of different poisons, &c. &c.; compare, I say, these hemorrhages, and many analogous ones that I could mention, with those that take place spontaneously from the mucous surfaces; you will see that they do not resemble them in their phenomena and their duration; that by suppressing them, they do not give rise to others; that they are independent of all kinds of sympathetic influence; that the passions have no effect upon their cessation or their production, whilst they have so powerful an influence upon the others.

Let us conclude from all these considerations, that all mucous hemorrhages, whether active or passive, are real exhalations. Hence you see that there is not so great a difference as might be thought, between the first and inflammation. In fact, in one there is an accumulation of blood in the capillary system, then the passage of this fluid by the exhalant vessels, that are continuous with this system. In the other, there is only the first phenomenon. Undoubtedly the signs, the circumstances, &c. are wholly different, because the modifications the organic sensibility undergoes are not the same; but the state in which the small vessels and the blood are respectively found, is not less analogous. One proof that in active hemorrhages, it is the organic sensibility which, differently modified, opens or closes the passage to the blood by the exhalants, is this, that almost always there are previous symptoms which continue for some time, and which evidently declare the disturbance that the vital forces, the organic sensibility in particular, experience in

the part; we know the itching, the forerunner of nasal hemorrhages, the tickling and sometimes sense of heat which precede the pectoral. Sometimes, according to the varieties of alteration it undergoes, the organic sensibility at first permits serous fluids to pass, then bloody; this is what we see in menstruation, in which the exhalants oftentimes pour out serum for some minutes, then true blood.

In passive hemorrhages, the organic sensibility is without doubt diminished, as well as the tone or insensible organic contractility. We might say, that the small vessels were not able then to contract sufficiently to retain the blood; it is as in our injections which ooze from the mucous surfaces, because life no longer opposes their passage. Observe that when these hemorrhages are produced by an organic disease, it is almost always that portion of mucous surface nearest the organ, that is influenced by it. Thus in the last stages of disease of the heart or the lungs, the patients often spit blood; they pass it by stool, towards the termination of those of the liver, or even throw it up by vomiting, &c. The whole mucous system never loses its forces so as to pour out blood everywhere; it is only in a determinate part that it is weakened.

What disposes the mucous exhalants more than all the others to pour out blood? It appears to be because the capillary system whence they arise is constantly entered by blood, and the course is very short from this fluid when present in the capillaries to the mucous surfaces. This is so true, that those portions of the mucous system that have but little of this fluid in a natural state, as those of the sinuses of the face, of the ear, &c. are less subject to hemorrhages. I am confident, that if there were exhalants upon the muscles to pour out constantly a fluid upon the exterior of these organs, hemorrhages would be very frequent in them.

Hence we see that the mucous hemorrhages have nothing in common, but the extravasation of blood, with those which are the effect of hemorrhoids, and always suppose a rupture of the veins, with those that aneurisms or varices produce, with those that are the effect of a cut, of a violent concussion, &c. They form a class by themselves, and resemble those only that the exhalants furnish upon the other surfaces where they open.

If I should class hemorrhages, I should distinguish them, 1st, into those that come from exhalation; 2d, into those that are produced by rupture. I should place among the first the bloody sweats, the mucous, serous, cellular hemorrhages, &c.; among the second, those that accompany wounds, aneurisms, &c. In order to embrace in one view all the sanguineous evacuations that can happen in the animal economy, I think it absolutely necessary to adopt this division which moreover accords with the phenomena and treatment of hemorrhages. Would you bleed to arrest a hemorrhage from rupture? undoubtedly not; but you would bleed to check an active hemorrhage by exhalation, because by diminishing the mass of blood, you diminish the excess of organic sensibility which produces the hemorrhage; it is nearly the same as when we bleed for inflammation. It is certainly necessary that the hemorrhage should be stopped as it has been produced; it is necessary that the sensibility of the exhalants should return to its natural type before the blood ceases to flow. We do not bleed to draw the blood to another place, as has been said; if it was so it should be done in passive hemorrhages. Most of those who bleed much in hemorrhages, believe that plethora is the sole cause that produces them, that the vessels containing too much blood, require a part of it to be taken away; but there are many more cases of active hemorrhage in which there are no signs of plethora, than there are of those in which these signs exist. There may be a real deficiency

of this fluid in the great vessels, but if the exhalants of a part are by their peculiar sensibility in relation with it, they will pour it out in as great abundance as if there was an excess of it. It is as in the increase of natural secretions, exhalations, &c. Whether there was plethora or not in the great vessels, when the local affection has raised the peculiar sensibility of the secretories or the exhalants, they would draw abundantly from the blood. The influence of plethora upon the increase of the different fluids which are separated from the blood, is evidently one of the remains of the opinions of Boerhaave. If the heart agitated everywhere the fluids, if it propelled the blood, the serum, &c. that go out by the exhalants, the secreted fluids that go out by their ducts, this influence would necessarily be real; but since all the fluids going from the capillary system are necessarily beyond every action of the heart, as in their circulation, they are wholly under that of the organic sensibility and tone of the capillaries, it is evident that these fluids are independent of the quantity of blood contained in the great vessels and moved by the heart; that the alterations of the vital forces of the part are the sole causes of the different phenomena that their course exhibits.

Who does not know that feeble and delicate temperaments are often subject in women to a much more copious menstruation than those that are stronger, more vigorous, more sanguineous, as it is called? You will find many results in authors, upon the quantity of blood evacuated by the catamenia, and you will observe at the same time that these results do not resemble each other; why? because each womb has, if you may so say, its own temperament, which oftentimes does not correspond with the general temperament, because each is disposed consequently to a different kind of vitality. There is more or less blood then given at each menstruation, as it is given for a greater or less time, for some women have at first

only a serous fluid, while others have blood immediately. I cannot repeat it too much, that every vital phenomenon is necessarily subjected to many irregularities, which arise from those to which the vital forces are themselves exposed. On the contrary, every physical phenomenon is almost immutable, because it is the nature of physical laws to remain always the same.

Hence we see how hemorrhages of the great arteries, which are under the immediate influence of the heart, should differ essentially from those of the capillary system and of the exhalants, whose phenomena are under the influence of the forces of the part where they happen, whether they arise from rupture or exhalation. Though in fact these two classes may be essentially different in their principal phenomena, as I have already said, yet they approximate, because the modifications of the vital forces of the part have a necessary influence upon them when they are in the capillary system. Thus astringents, tonics, styptics and other medicines which evidently act upon the organic sensibility and the insensible contractility, frequently stop hemorrhages of the capillary system. The contact of the air, by modifying these properties in wounds is even sufficient to produce this effect. On the contrary, ligatures alone can, in the great vessels, resist the powerful influence of the heart. All styptics imaginable may be heaped upon an open artery, and they would not check the effect of this influence. This then is the essential difference between the hemorrhages of the capillaries and exhalants, and those of the arteries, that every medicine which acts upon the organic sensibility and tone, can be advantageously employed for the first, whereas they have no effect upon the second. I go now to the sanguineous exhalations which are made by the recrementitious exhalants.

Hemorrhages of the Recrementitious Exhalants.

The serous membranes are the frequent seat of hemorrhages. The examination of dead bodies incontestably proves it. Nothing is more common than to find in the peritoneum, the pleura, the pericardium, &c. a serum, reddish if a little blood is effused, very red if more, and even pure blood is found under certain circumstances.

I have made these observations in two different cases, 1st. After inflammations whether acute or chronic, especially the last. The serous sac then contains a greater or less quantity of blood, sometimes alone, more frequently mixed with serum, and now and then even with whitish and albuminous flakes. The previous inflammation seems to rank these hemorrhages among the active. 2d. Often at the end of organic diseases, in which the exhalations of serum increase almost uniformly in the serous sacs so as to produce dropsies evidently passive, a greater or less quantity of blood is mixed with this serum. What anatomist has not observed these bloody effusions in the pericardium, the pleura, &c.? I have observed that the tunica vaginalis and arachnoides are infinitely less subject to them than other similar sacs; I have never seen them in the last, and twice only in the first. I of course do not speak of the hemorrhages that are the effects of wounds of the head and in which the blood is effused between the two folds of the arachnoides.

I have carefully examined the internal surface of the peritoneum, the pleura, and the pericardium, after this kind of hemorrhages, produced either in consequence of the inflammation of the membrane itself, or of an organic disease; their surface has appeared to me to be perfectly sound, so that it is very evident that the exhalants have furnished blood, instead of the serum they threw out there before.

I compare a serous surface preternaturally pouring out blood after inflammation, with the active hemorrhages of the mucous surfaces. On the other hand, when the serous exhalants throw out blood at the end of organic diseases of the heart, the womb, the lungs, &c. it is certainly the same phenomenon, as when blood brought by the mucous exhalants, under like circumstances, is thrown off by spitting, vomiting, or stool.

Are there cases during life, in which the blood, poured out by exhalation upon the serous surfaces, is afterwards taken up by absorption? I believe that it may happen after inflammation, though we are possessed of no positive facts upon the subject. Cruikshank and Mascagni have seen the blood absorbed by lymphatic vessels, after wounds of the chest; why might not that happen after hemorrhages by exhalation, which takes place after those from rupture?

The cellular exhalants frequently pour out blood in the cells. 1st. This phenomenon is often very evident in phlegmon or in other similar tumours. By cutting into them, in the dead body, we find blood extravasated in the cells; this is so true, that some authors have made the nature of inflammation consist in this extravasation. But in slight phlegmonous inflammation, the blood undoubtedly remains in the cellular capillary system; it is only in those cases where the inflammation is very great, that this passage takes place. 2d. As to the passive hemorrhages of the cellular texture, who does not know that oftentimes the water in dropsies is reddish? who does not know, that in scurvy, considerable portions of the cellular texture are infiltrated with blood, which has certainly not been poured out by erosion? I injected not long since two subjects, with very evident scorbutic spots on the legs, and there was no kind of extravasation in them; there would have been if the rupture of the vessels produced these spots. As these things did not arrest

my attention particularly in former years, I did not pay much attention to many subjects that I have injected with these scorbutic spots. I do not think that they would ever have presented cellular effusions, which would undoubtedly have struck me if they were there, when I dissected bodies for the students.

As to the hemorrhages of the medullary exhalants, we are ignorant of them. I have never seen in examinations of dead bodies, blood effused in the articulations, except from wounds, &c.

As to the nutritive exhalants, it is evident that every sanguineous exhalation is foreign to them.

Preternatural Exhalations, not Sanguineous.

The blood is not the only fluid that sometimes passes by the exhalants instead of the fluids that these small vessels naturally pour out. Who does not know how much the sweat differs? Sometimes water is almost alone transmitted by the skin; at other times the sweat is filled with many substances more or less heterogeneous; it is more or less salt; we know how very different at times is the odour of it. Observe the many substances that are thrown out upon the external surface by the exhalants, in the small pox, measles, scarlatina, &c. in herpetic affections, in different eruptions; compare the critical sweats with those that are natural, and you will see that the exhalants are, if I may so express myself, a common passage, which all the substances contained in the body can pass through, and which in fact they do pass through in certain cases, when, among the numerous modifications of which the cutaneous organic sensibility is susceptible, they find those that are in relation with them. Shall I speak of the serous exhalants? observe that the surfaces of the same name, according as they are affected, pour out many different fluids, a milky serum, and a thick substance that attaches itself to their surface in the form of a com-

pact membrane, &c. If you have opened but little the bodies of those who have died of chronic peritonitis, you must have been astonished at the diversity of fluids then contained in the peritoneum. Grey, yellowish, fetid, without odour, thick, viscid, thin, &c. &c. these fluids are hardly twice the same. The serum appears to be always the general vehicle; but the substances that it contains, by the effect of the change that disease has produced in the vital forces of the membrane, are infinitely variable.

Thus we shall see that the glands are a common way, through which pass, according to the manner in which they are affected, many substances which differ essentially from those that compose the secreted fluids in the natural state.

IV. *Of the Preternatural Development of the Exhalants.*

The exhalants are developed preternaturally in many parts; it is especially in the cysts that this development is best seen. Their internal surface, ordinarily smooth, pours out very different fluids, according to the particular sensibility they possess. When we open these cysts, the exhalants furnish new fluids, and it is often necessary to remove them to prevent exhalation. Sometimes instead of the fluid that is ordinarily exhaled there, the blood is thrown out, as happens on the serous surfaces; for example, I have found very bloody serum in the encysted dropsies of the ovarium; latterly I have seen in them coagulated blood. I would observe that this is an essential difference to be added to those mentioned above, between the fluids that are exhaled and those that are secreted. These last are never preternaturally poured out in a cyst. We never find preternaturally a quantity of bile, of urine, saliva, serum, &c. whilst we often find serum, as in encysted dropsies, fat as in steatoma and other tumours which have a fatty liquid analogous to this

fluid, synovia, as in the tumours called ganglions, when they are not dilatations of the synovial glands, which have cysts preternaturally produced, &c. Whence arises this difference? it would be necessary that the glands should be preternaturally developed in our parts, in order that the secreted fluids might be preternaturally separated from the blood, now the structure of these organs is too complicated, their organization supposes too many conditions, to admit of their preternatural development. On the contrary, the simple organization of the exhalant surfaces, which have only vessels continuous with the arteries, and without an intermediate organ, requires much less for them to grow preternaturally in parts, in which they were before unknown.

Sometimes the fluids exhaled preternaturally do not collect in a cyst; they continually flow out; this is what takes place in fistulas, and other preternatural or artificial drains that are made in our organs. Then the cellular texture, constantly preserving the preternatural modification of sensibility that it has taken locally from a deposit, or any other circumstance, constantly continues to pour out a fluid different from the serum that is exhaled in a natural state.

ABSORBENT SYSTEM.

THIS system results from the union of a multitude of small vessels which arise from all the parts, and carry different fluids that are poured into the black blood, after having passed through certain peculiar swellings that are called lymphatic glands, and which make a part of the system with them. The whole of the absorbent system comprehends then two things, 1st, the vessels; 2d, the swellings or glands, an improper name, inasmuch as it assimilates them with organs which pour out fluids by the excretories that arise from them.

ARTICLE FIRST.

Of the Absorbent Vessels.

WE shall examine these vessels in their origin, their course and their termination.

I. *Origin of the Absorbents.*

The origin of the absorbents can hardly be demonstrated by inspection; it is like the termination of the exhalants. Such is in fact the extreme delicacy of these vessels at

their origin, in most parts, that they cannot be seen with the best optical instruments. In some places we see pores; but it is difficult to distinguish their nature, whether they are exhalant or absorbent. Their origin then must be determined by the phenomena they produce in different places. Wherever absorption takes place, it is evident that there they begin. Now in examining attentively the phenomena of absorptions, we see that they are discoverable whenever there are exhalations; so that the same table may serve both for the absorbents and the exhalants; the following is the table for the first.

ABSORBENTS.	1st. exterior, arising from the systems	1st. mucous.	
		2d. dermoid.	
	2d. interior, arising from the systems	1st. serous.	
		2d. cellular, and taking up there,	1st. fat.
			2d. serum.
		3d. medullary	1st. the short and flat bones, and the extremities of the long ones.
			2d. the middle of the long bones.
		4th. synovial.	1st. the articulations.
			2d. the tendinous grooves.
	3d. of nutrition.		

Let us examine these different absorptions, of which I shall not give the proofs here in detail, because these proofs will be shown in each system from which the absorbents arise. 1st. The external absorptions do not correspond precisely with the exhalations of the same nature. In fact, neither the sweat nor insensible transpiration exhaled by the skin, are taken up by the cutaneous absorbents: these fluids are excrementitious. So the mucous absorbents allow the pulmonary transpiration to evaporate, and the other fluids exhaled upon their surface, to mix with the aliments and afterwards to pass off. It is the substances contained in the atmosphere, in the surrounding bodies, &c. that this kind of vessels takes up by a very irregular absorption, as we shall see, except however

that of the chyle, which is not made in a continuous manner, which is subject to great intermissions, and which at other times takes place with remarkable activity.

2d. The internal absorptions, on the contrary, every where correspond with the analogous exhalations. Thus the absorbents take up, upon the serous system, the serum, upon the cellular system the serum and fat, upon the medullary system the marrow, upon the synovial system, the synovia; fluids, all of which as we have seen, had been thrown out by exhalation upon their respective surfaces, and had remained for an instant upon them. These absorptions are made in a constant and regular manner; it is in this that they differ from the preceding. The internal absorbents, incessantly in action, take up in a given time the same quantity of fluids; their action corresponds precisely with that of the exhalants. Observe that there are two essential differences between the external and internal absorptions; viz. that the one are exerted on the one hand on fluids different from those exhaled upon their surfaces, and that on the other they are subject to continual variations and irregularities; whilst the others always take up the fluids exhaled upon their surfaces, and are constant and regular, at least in a state of health. I shall point out in the mucous and cutaneous systems, the cause of this important difference.

3d. As to the nutritive absorptions, we know much less of them than the preceding; but nutrition evidently supposes them. There is in fact in this function a double motion, one of composition, the other of decomposition. No organ, no part of an organ is formed at one period of the same elements that composed it at a former one. The ancients thought, without positive proof, that the body was renewed every seven years. Whatever may be the period of its renewal, we cannot deny that it is continually composed and decomposed; now the exhalants perform the first nutritive motion, the absorbents the second.

Observe in fact, that the internal substances never re-enter the circulation to be afterwards thrown out, except by the way of the absorbents.

The nutritive absorptions differ then from the preceding, in this, that the substance deposited by exhalation and taken up by them, remains in the organs, makes a part of them, and contributes to their composition; whilst the fluids with which the internal exhalations and absorptions are concerned, after having been furnished by the one, and before being taken up by the other, remain out of the organs, upon their surface or in their cells, but do not make a part of their structure.

It is difficult perhaps to conceive how solid nutritive substances can be absorbed by vessels so delicate. Hunter, to whom anatomy owes much both as it respects the absorbents and their uses, has already removed this objection. It may be added to what he has said, that the distinction between solids and fluids is not substantial except when they are in mass; but when they are considered as separate particles, they do not differ; this is so true, that the same particle makes alternately part of a solid and a fluid, as in water that is not frozen and that which is, as in solid or melted lead, &c. Now the nutritive substances are absorbed particle by particle; then the distinction of fluid and solid is of no consequence in the function of absorption.

Since the origin of the absorbents is beyond the reach of our senses, it is difficult, it is impossible even to determine the manner in which they arise, the peculiar structure which distinguishes them at their origin, their communications, &c. They undoubtedly differ essentially according to the mucous, cutaneous, serous, synovial, cellular, medullary surfaces to which they belong; undoubtedly the nutritive absorbents differ remarkably from the others; but nothing can be proved by inspection. What has not been said upon the villous coat of the in-

testines considered as the origin of the lacteals, upon their small bladders, upon the form of the pores of the peritoneum, the pleura, &c. upon the cellular sponge? I shall not notice here these anatomical hypotheses, which have been made by an abuse of the microscope, and which besides, if they had any real foundation, would not lead to any inference useful to science.

Do the absorbents arise from the capillary system? Judging by injections, it would seem that they did, for many distinguished anatomists, by forcing a fine injection through the arteries, have filled the absorbents in the neighbourhood. I never saw any thing similar to it myself, yet I am far from denying a fact attested by Meckel. If many other experiments should confirm it, it would be established incontestably, it is evident, that the origin of the absorbents is in the capillary system, as the origin of the excretories and exhalants are proved to be in the same system. Besides, the phenomena of absorptions cannot give us any light upon the mode of the origin of the absorbents.

Where they go off from the surfaces or the organs from which they arise, the absorbents are extremely delicate; they elude all kinds of injection. They appear to anastomose with each other, interlace, form a complicated net-work, which contributes much to the structure of some parts, especially of the serous membranes. We know however but little of this interlacing. It is not until they have run a certain course, that these vessels are cognizable by our senses, and that we can consequently study them in a general manner.

II. *Course of the Absorbents.*

The absorbents, arising from the different parts that we have pointed out, go in different ways.

1st. In the extremities, they are divided immediately into two very distinct courses, the one superficial, the

other deep-seated. The former accompanies at first the sub-cutaneous veins, then runs along in their interstices; so that when injections have succeeded well, the whole exterior of the limbs appears to be covered with a kind of lymphatic net-work. The second goes along the muscular interstices, principally in the course of the arteries and the veins. Both tend towards the superior parts of the limbs. When the vessels arrive there, they approximate each other, and are collected into a bundle, in which they are fewer but larger than below, and which passes through certain openings that lead them into the trunk; for example, those of the superior extremities almost all terminate in the axilla, those of the inferior in the groin and some in the ischiatic notch. Now as it is a general rule, that every absorbent should pass through one or more glands, nature has placed at these openings of communication of the extremities with the trunk, a certain number of these glands. Yet before arriving at them, some have already passed through similar glands placed, in a less number, it is true, in the ham and the bend of the arm. It is in the extremities that the absorbents run the longest course without passing through glands.

2d. In the trunk, the absorbents take at first two courses, the one sub-cutaneous, the other deep-seated, which is found upon the internal surface of the parietes of the cavities, for example, between these parietes and the peritoneum in the abdomen, between these parietes and the pleura in the thorax. The first belongs especially to the fleshy parietes and the abundant cellular texture that is found on them. The second belongs to these parietes and the serous surface that lines them. Besides these absorbents, each viscus contained in the preceding cavities, has deep-seated and superficial ones; the first go into the interior of the organ, we see the second on the surface. This distinction is easily made upon the liver, the spleen, &c. The external absorbents

of the parietes of the trunk, run a long course without meeting with glands. Those that are spread on the internal surface of these parietes exhibit a similar arrangement. But those of the viscera hardly come out of them, before they meet these glands, and pass through a great number at a time, because they are very near each other.

3d. There are many absorbents upon the exterior of the cranium ; but anatomists have not yet found them in its cavity, which agrees perhaps with the almost total absence of cellular texture in this cavity. There are many on the face, superficially, in the muscular interstices, and around the organs that occupy this region. They descend to the neck, where they find in their course a very great number of glands which they successively pass through.

Form of the Absorbents in their course.

The absorbents differ essentially from the veins in this, that for a great distance they keep of the same size. Whilst in the venous system the vessels are constantly becoming larger, so that a branch can hardly go a few inches without doubling its size, those in the absorbent system remain for a long time the same. When injected these vessels appear like long white threads running upon the organs.

It follows hence, 1st. that the lymph never circulates like the blood, in considerable masses, but always in very fine streams ; 2d. that the absorbents are very numerous ; for their number compensates for their size ; thus all the surfaces are covered with them, whilst they have but few veins and those of considerable size ; 3d. that the absorbent system has not really the form of a tree, like the arterial and venous systems ; the manner of division is wholly different. The absorbents are very commonly straight ; when they are tortuous, their curves are entirely unlike those of the veins or the arteries. In fact

in these last, when the tubes have become as fine as the absorbents, their curves are brought near each other and are small in proportion to the size of the vessel. On the contrary the windings of the absorbents are great; the curves that result from them have often a very considerable extent; they wind in long folds upon the extremities, when they are not straight there.

Viewed externally, the absorbents are not always cylindrical. When filled with injection, they often appear full of knots; this undoubtedly arises principally from the valves. Many authors have represented them as a series of successive contractions; this is however true only to a certain extent.

I have often seen in living animals, in dogs in particular, evident dilatations, a kind of little bladders in the course of a lymphatic, containing serum. It is upon the concave surface of the liver and the gall-bladder, that I have most often observed them. When these bladders are pricked with a lancet, the fluid flows out and they disappear immediately. In making experiments with other views, I once saw two or three of these small dilatations in the neighbourhood of the gall-bladder. Having suffered the liver to fall back, to examine the intestines, I was astonished at not being able to find them an instant after; they disappeared without doubt by the contraction of the vessel. I would remark upon this subject, that the liver is the organ upon which these vessels are best seen in living animals; but it is necessary to examine its concave face the instant the abdomen is opened; for the contact of the air by contracting them, soon prevents their being distinguished.

Besides I believe that in no case are the absorbents as much distended during life by serum, as they are by mercury from injections. When these have succeeded well, we see upon many parts a net-work of very evident vessels. On the contrary, most commonly nothing simi-

lar is to be seen in living animals. With whatever promptness we examine most of the surfaces which the serous membranes cover, surfaces that can be laid bare without making the blood flow, nothing is seen, except sometimes small transparent striæ, which soon disappear. Now it is impossible that if the absorbents were as full during life, as they are by injections, but what their transparency contrasted with the colour of the surrounding parts, would render them evident. I have selected however very large dogs, to try to see their course better. I believe that injections double at least the diameter of these vessels.

Of the Capacity of the Absorbents in their course.

The capacity of the absorbents is remarkably variable; it depends entirely, in the dead body, on the state in which these vessels were in the last moments. In subjects of the same stature and age, they are sometimes very apparent, at others hardly visible. They are double, treble even, in some dropsical patients, what they are in a natural state. Many authors say that they have seen branches almost equal to the thoracic duct, and larger than the trunk of the right side. To be convinced of the extreme variety of the absorbents, without the assistance of injections, take the lymphatic glands in different places, then dissect carefully the parts in the neighbourhood; you will easily find all the absorbents that go to them. Then you will be able to satisfy yourself of the extreme variety of their size; we can even in this way trace them far enough without injection. Sometimes in order to find the end of the thoracic duct, I take a gland in the neighbourhood of the second lumbar vertebra; thus following the empty lymphatic tubes that go from it towards the canal, I find it without difficulty.

When we are not in the habit of finding immediately the absorbents, this method of searching for them by

means of the glands, which are always very evident, infallibly succeeds; it cannot be used it is true in the extremities; but in the thorax and especially in the abdomen, it is very convenient. For example, by taking the inguinal glands we can trace these vessels to the thoracic duct, by injecting them, or even without. Some authors have advised making an opening in the gland and placing a tube in it; this rarely succeeds; it is much better to open the vessels that go from the gland, at the place where they go off.

The absorbents usually flat in the dead body, because they are empty, never exhibit in this state a diameter proportional to that which injections give them; whatever may be the varieties of capacity, the fluids that we force into them always increase this capacity. It is this flattening after death, that often makes us in attempting to open them with a lancet, cut through both their parietes, and thus render it more difficult to inject them.

The best proof of the extreme variety of the capacity of the absorbents, is the necessity of choosing particular bodies in order to inject them, the very great difficulties that often take place in finding them in some subjects, whilst they are seen immediately in others, and can be traced in the inferior and superior extremities, through the cellular texture, without having glands for a guide. It is not necessary then, after what has been said, to consider the caliber of the absorbent vessels in a determinate manner. Constantly varying, according to the state of the lymph they contain, they have no standard size to which we can refer their increase or diminution. This is the peculiarity of all the extensible and contractile canals, like those in the animal economy; it is that which prevents us from making any kind of calculation of their capacity.

These varieties of the absorbents are not general as in the veins, all the great trunks of which, for example, are

simultaneously dilated when there is an obstruction in the lungs. Here sometimes one only, sometimes many branches enlarge; the others remain contracted. Sometimes the dilatation is general in a part, very often there are remarkable disproportions of capacity in the same vessel; it is double in one place what it is in another, though it has not received branches.

Authors have been much puzzled to determine the capacity of the thoracic duct. I believe it, for it is never found twice the same. These varieties do not depend on the constitution of the subject, but only on the functions, and the state in which these functions are found at death. Whether it be dilated above, contracted in the middle, exhibiting below a little bladder, called by some the reservoir of the chyle, &c. are circumstances the greatest number of which vary incessantly during life, according to the quantity, the nature of the lymph, and the obstacles to its course in this or that part. We find a hundred varieties of the thoracic duct and the absorbents in a hundred different subjects. The same subject has perhaps undergone these hundred varieties at the different periods of his life. If life returned and was destroyed many times in the same man, the venous and absorbent systems would exhibit a number of varieties equal to the number of times he had died.

We see from these considerations to what are reduced all these minute examinations of proportion in the capacity of the vessels, which fill our books of physiology.

If we compare the amount of the veins with those of the absorbents, it is difficult undoubtedly after what has been said, to form any precise idea of it; but we can make approximations. Now the absorbents do not appear hardly inferior to the veins; as to the branches, for example, the whole of the lymphatics of the lower limbs, placed by the side of the capacity of the venous trunks, does not appear much inferior to it. So in all the other

parts, the veins being larger, but the absorbents more numerous, the disproportion is not very great.

From this it seems as if there would be but little difference between the trunks that terminate the veins and those that are the terminations of the exhalant system; however this difference is enormous, as we shall see.

Anastomoses of the Absorbents, in their course.

In the extremities, on the exterior of the trunk and the head, in the intermuscular spaces, &c. the anastomoses are very evident. We see branches of communication going from one absorbent to another; so that we might often say that these vessels are bifurcated. But this appearance is most usually deceptive; for each branch of the bifurcation is almost always as large as the trunk.

Under the serous surfaces, as on the convex face of the liver, the lungs, the spleen, &c. the anastomoses are infinitely more numerous; it is a kind of net-work in the plates of authors; for I confess that I have never injected this portion of the absorbent system.

The anastomoses of the absorbents are made, 1st. from one vessel to another that is contiguous to it; 2d. from the sub-cutaneous divisions to the intermuscular in the extremities, and in the organs, from the sub-serous divisions to those that occupy the interior of these organs. 3d. They take place between the absorbents of the superior regions and those of the inferior; 4th. between those that go to the thoracic duct and those that go to the great lymphatic vessel of the right side, &c.

By these anastomoses we understand how a tube with mercury, being placed in one absorbent, many others around it are filled. They are so much the more necessary, in the system of which we are treating, as the lymph is subject, like the black blood, to an infinite variety of causes of delay in its course, from the want of an agent of impulse at the origin of the absorbents.

Gravity, external motions, different compressions, &c. have upon the motion of this fluid, the same influence as upon that of the veins; gravity especially has much influence. We know that if the powers are a little diminished after long diseases, too long standing renders the legs oedematous; hence why they are always more swelled in the evening than in the morning. As to compression, if it is only moderately great and acts upon many absorbents, it also produces oedema. It is not the size of the surface compressed that has an influence upon this phenomenon; it is only the number of absorbents that pass through this surface. Thus by the head of the humerus being in the axilla, the arm is frequently made to swell, whilst more extensive compressions across the deltoid muscle, where there are fewer absorbents, do not produce this effect.

From these phenomena, it is necessary then that there should be the same means to favour the lymphatic circulation, that there are to aid the venous. These means are especially the anastomoses; it is by them that the first of these circulations is continued, notwithstanding all the external obstacles that our clothes in certain places create, notwithstanding the different pressure that the organs make upon each other. It is only when the whole of the absorbents of a part is compressed, that the motion of the lymph is interrupted. Thus the womb becoming very large in pregnancy, and pressing upon all those of the lower extremities, these extremities become dropsical. I hardly know any organ in the abdomen but this, which by its position can produce these general infiltrations by compression. The liver and all the other organs are not capable of producing a similar phenomenon. When dropsy takes place from an affection of them, it is rather because the functions of the exhalants are increased.

Remarks upon the Difference of Dropsies that are produced by the increase of exhalation, and those that are the effect of a diminution of absorption.

This leads to an observation that appears to me to be very important in dropsies, viz. the determining when the defect of the action of the absorbents produces them, and when they arise from the increase of that of the exhalants.

1st. Whenever a tight ligature applied to a limb makes the lower part swell, whenever too long standing, a perpendicular position of the superior extremities, &c. produce the same effect, it is to be presumed that the effusion depends upon the compression of the lymphatics, and takes place then like venous dilatations in similar circumstances, because the lymph finds it difficult to circulate. Here then is a case in which the exhalants have nothing to do with the dropsy, which takes place because the absorbents do not take up what the exhalants furnish. If other causes, as a bruise, a wound, &c. diminish the activity of the part, the absorbents directly weakened, are not able to take up their fluids. So if their weakness is sympathetic, that is to say, if it arises from the injury of another viscus, the same phenomenon will be the result of it. In all these cases we find the absorbents much dilated in the dead body: often they are even full of fluids.

2d. But in the organic affections to which dropsy succeeds, the exhalants certainly in the greatest number of cases, pour out more fluids than usual. The pleura is filled in phthisis, the skin is then covered with night sweats, blood is raised, &c. These are the exhalations which I have called passive. They are so abundant on the serous surfaces, that if a puncture is made, the peritoneum often fills again with such rapidity, that as much water is collected in a day, as there would be in a month, if the exhalation was natural. I do not say that the absorbents are not also affected in these cases; but the principal

cause of the dropsical effusions is certainly then in the increased action of the exhalants. I could cite other examples, but this is sufficient. Four years since I was engaged upon the absorbents; I observed then that these vessels are not always very evident in dropsical patients, notwithstanding what has been said by many authors, and that very often we see them more easily in very thin subjects. I had not then thought of this difference of dropsies; but in working again upon this system for my Descriptive Anatomy, I think of comparing the cases in which it is dilated and those in which it is not, with the cause of the death.

III. *Termination of the Absorbents.*

All the known absorbents unite into two principal trunks. One of these, which is the thoracic duct, receives all those from the lower extremities, abdomen, the greater part of the thorax, and those of the left side of the superior parts. The other is formed by the union of the absorbents of the right side of the superior parts, as well of the head, as the extremities, and of some of those of the thorax. These two principal trunks go into the vena cava superior; around them, many smaller branches also terminate there.

If we examine but little the number of the absorbents distributed in all the parts, it will be easily understood, how enormous the disproportion of their capacity is with that of these two trunks. How is it that all the serum contained upon the serous surfaces and in the cellular texture, that all the residuum of nutrition, that all the fat, the medullary fluid, and synovia, that all the drinks, all the product of the solid aliments that constantly enter the circulation, can pass, in order to get there, through vessels so small? This observation has struck all authors; and it is, I confess, very difficult to explain. In

fact, 1st. When there is a disproportion in the capacity of the blood vessels, it is compensated for by an increase of velocity where the caliber is less; thus, though the capacity of the veins exceeds that of the pulmonary artery, still all the blood of the first passes through the second. Now if we examine in a dog the thoracic duct during digestion, which can easily be done by opening quickly the thorax on the right side, raising the lungs of that side, and by cutting the pleura along the aorta, which allows you to see immediately this canal then very white on account of the chyle that is passing through it, if, I say, we examine the thoracic duct in action, we shall see that the circulation goes on there nearly as in the veins. By opening it then, a more powerful throw of fluid does not indicate a greater velocity than that of the venous blood. 2d. It might perhaps be said that during life the thoracic duct is sufficiently dilated to correspond to all the absorbents; but observation proves precisely the contrary. The thoracic duct, full of chyle, is undoubtedly a little more dilated than in the dead body; but I have satisfied myself repeatedly that the difference is not very great. 3d. By supposing that a great quantity of fluids passes through the thoracic duct, notwithstanding its size, the vena cava superior ought to be proportionably dilated between it and the heart; yet it continues nearly of the same size after having received this canal. 4th. Hewson, by taking the fluid of the lymphatics, has proved that it was analogous to that of the serous surfaces; its transparency, when examined in the vessels of a living animal, makes me also believe it, though this would not be a conclusive reason. How can a fluid of the same kind, result from the combination of such different elements, viz. of those which compose the mucous, cutaneous, nutritive, fatty absorptions, &c.

I confess that the different substances that enter the black blood by the thoracic duct and the one correspond-

ing to it, may enter it at different times; that the lymph, the fat, the chyle can each have their time of passing. But first this explanation is not supported by any fact, and the disproportion would also then be very great.

Many distinguished anatomists have thought that the veins absorb, and in relation, to their use, they have joined these vessels to the lymphatics. Haller, Meckel, and before them, Kaw Boerhaave, were of this opinion. Such names deserve undoubtedly an examination of the reasons advanced; let us now consider these reasons. 1st. The thoracic duct has been seen obliterated, and absorption continuing to go on, while life was preserved in the animal. But as they have not observed whether the great right lymphatic and its accessories were obliterated, nothing can be concluded from this fact. Besides the observations upon this point do not appear to me to be well ascertained. They could decide this question very easily, I think, by tying during digestion, the thoracic duct at its entrance into the jugular; it could be readily come at on the inferior part of the neck, where it could be distinguished by its whiteness; no important part need be wounded. This experiment would throw great light upon the general question of absorptions. 2d. Fine injections, made through the mesenteric vein, cover the peritoneum; hence it has been concluded that the absorbents terminate in this vein. But as the venous extremities communicate with the capillary system, and as this gives rise to the exhalants, injections, by going through its numerous anastomoses, can easily be spread in this way, which vitality shuts during life, but which the flaccidity of the parts and the absence of sensibility open after death. 3d. Compression of the superficial veins produces swelling of the limbs; but as this compression is made at the same time upon the absorbents, no inference respecting venous absorption can be drawn from it. 4th. Kaw Boerhaave having introduced water into the intesti-

nal canal, it was afterwards found in the mesenteric veins; but this experiment has been many times repeated since without giving the same result. 5th. Add to these considerations the numerous experiments of Dr. Hunter, to prove that venous absorption does not take place on the surface of the intestines, and you will see that this absorption will appear very uncertain, in these first respects.

But if you look at the question in other respects, you will be unable to deny that certain facts present probabilities in favour of this absorption. 1st. It is almost certain, that the venous extremities take up by the way of absorption, the blood effused in the corpus cavernosum. 2d. We do not see absorbents in the placenta, and yet the umbilical vein takes up all the fluids of this body. 3d. Meckel having injected a lymphatic vessel that went to a gland, the injected mercury passed into a neighbouring vein.

All these observations throw great obscurity upon the termination of the absorbents. I think that if on the one hand, we cannot doubt that the greatest number of these vessels, those especially that come from the serous surfaces, from the cellular texture, from the intestines, have known terminations, we ought on the other to suspend our judgment as to the manner in which the others terminate, and that the question must remain wholly undecided upon this point, till it has been settled by new experiments. Here, as in so many other points, physiology has need of great light. 1st. The enormous disprotion between the absorbents and their common trunks; 2d, the impossibility of understanding from the analogy of the veins, the lymphatic circulation, with the apparatus that injections exhibit as its vessels; 3d, many probabilities against and many in favour of venous absorption; 4th, no other known way for the fluids which enter the blood by the absorbents, than the trunks noticed above. There is

nothing but obscurity and contradiction in the different data which would assist us to resolve this problem.

IV. *Structure of the Absorbents.*

This structure, capable only of being seen in the great trunks, the thoracic duct, for example, presents us at first in its common organization, a layer of dense cellular texture, of the same nature as that of which we have already so often spoken, of which we shall speak again, and which is found around the arteries, the veins, the excretories, under the mucous surfaces, &c. &c. This filamentous texture, connected only to a certain degree with the vessel, strengthens it however much, by surrounding it with an external membrane superadded to that which is peculiar to it. If, as Cruikshank has done, we turn this duct inside out, and introduce into it a tube of glass of a diameter a little larger than its own, this last membrane will break. It is as in the arteries, in which a ligature cuts the internal membrane and not the cellular. The same phenomenon takes place from inflation; a much greater effort is necessary then to break the cellular texture, than to rupture the peculiar membrane of the thoracic duct.

No fleshy fibre is observed, in an evident manner at least, in the absorbents. Some authors have admitted that they were there, but injection contradicts them, even as it regards the thoracic duct. Blood vessels probably run over the parietes of the absorbents; in ordinary injections they are often very conspicuous on the thoracic duct. We know not if there are nerves there; there is but little appearance of them, if we may judge by the analogy of the veins, which have a great relation in structure with these vessels.

The internal membrane which forms the peculiar texture of the absorbents is continuous with that of the veins, and forms with it an uninterrupted series of small tubes,

Delicate, transparent, it is moistened in the dead body by an unctuous fluid, which is, I believe, unknown to it in the living, as that of the arteries is to those vessels. It adheres to the external membrane by a compact cellular texture, which, as in the veins, is rarely subject to ossification. Mascagni has however mentioned an instance of it in the absorbents of the pelvis. But there is another affection analogous to this, which I have already seen many times in this kind of vessels. Their cavity often contains a white matter, like plaster, especially on the external surface of the lungs. Then without any preparation, the absorbents exhibit almost the appearance which they have when mercury fills them.

The peculiar membrane, forms by its folds, valves similar to those of the veins, but much more numerous. We find these united two by two, rarely one exists alone. They leave between them small intervals, very variable however in extent. Hence it happens that the thoracic duct can sometimes be injected from above below through its whole extent, sometimes it receives the fluid only in a short space, according as the valves are more or less numerous in its cavity; which depends also much on the relation of their width to the caliber of the vessel, a relation which varies from the same causes as those assigned for the veins. Hence it happens, that an absorbent filled with injection does or does not exhibit in great number those knots, which, as we have said, indicate valves. Wherever a branch is united to a trunk two of these folds exist at the place of their junction. This is remarkable especially in the thoracic duct, which injected from above, presents a dilatation at the origin of each branch, because in this place the valves are opposed to the fluid. Not numerous in the superficial system of the organs covered by the serous membranes, as upon the convexity of the lungs, and the spleen, they easily allow the passage of the mercury from one division to another, and their ordi-

nary functions are supplied there by the great number of the anastomoses.

Their use is the same as in the veins, viz. to permit the ascent of the fluid, and to prevent its return; but they do not always fully do this. Injection often without difficulty overcomes some of them. In dropsies, in which the absorbents are full, if we raise the skin, we easily distinguish these vessels by their transparency; but soon, notwithstanding their valves, they become empty, and then cease to be visible. Different anatomists have forced air, and even other fluids, into a great number of the lymphatics, by means of the thoracic duct, and consequently in an opposite direction to their valves. All these phenomena do not suppose in these vessels, as in their common duct, varieties in the structure of the valves, in their width, &c. but only different degrees of dilatation and contraction, degrees that are, as I have said, independent of structure. In dilatation, the valves close the caliber less than in contraction.

The valves of the absorbents have the same form and the same arrangement as those of the veins; they partake, by their constant exemption from ossification, of the general character of the membrane from which they arise, and which, by folding, forms them.

ARTICLE SECOND.

LYMPHATIC GLANDS.

I. *Situation, Size, Forms, &c.*

THESE glands are scattered in the different parts in greater or less number. In the superior and inferior extremities, we find but a small number, except at the upper parts, the axilla and the groin. In the ham and at

the elbow there are some, and there are engravings of them at the instep. But upon the arm, the leg, the thigh, the fore-arm, &c. they are not found. It is about the articulations that all are met with; in this respect, we can say, that they are constantly increasing from the inferior to the superior, no doubt because in ascending the number of absorbents is continually increasing.

Not numerous on the cranium, they are only on the exterior of this cavity, no one has ever, I believe, been found within it; which proves, perhaps, that it is not the tenuity of the absorbents that conceals them from us there, but that it is because they are of a peculiar nature and different from that of the others. The face contains many of these glands, especially along the stenonian duct, upon the buccinator, &c.

As to the trunk, if we take the vertebral column for a term of comparison, we shall see that there are but very few lymphatic glands, hardly any at its posterior part, and that they are very numerous anteriorly. On the neck, the jugulars are accompanied by a great series of these glands. In the thorax, the posterior mediastinum contains many of them. In the abdomen, they are abundant along the vertebral column, behind the mesentery.

The whole interior of the thoracic and abdominal cavities, considered otherwise than as it respects the spine, is also furnished with them. They are very near each other in the mesentery, at the root of the lungs, around the bronchiæ and in the pelvis. We see from this arrangement, that, 1st. the lymphatic glands are found in general more numerous in the places where the cellular texture predominates, in which they are, as it were, buried, a remarkable relation for which we are unable to assign precisely the reason. There are but few parts abounding with this texture, that do not also abound with lymphatic glands, and reciprocally there are none of these glands where it is wanting. 2d. We see also that the

parts the most distant from the common trunks of the absorbents, as the extremities, the head, the back, &c. are less provided with these glands; that the nearer we approach these common trunks, the more numerous they become; so that we might say that they form around them a sort of boundary, which separates them from the secondary absorbents, and which at the same time makes them communicate with them.

The size of the lymphatic glands, is variable, from the tenth of a line in diameter, to the size of a hazle-nut, and even larger. They are oftentimes so small that we can with difficulty discover them, and they cannot sometimes be seen until disease has developed them. Their increase in size is an ordinary effect of scrophulous affections, which often show us lymphatic glands in places where we did not know that they existed, especially on certain parts of the face and neck. We cannot say then that the swellings of the cellular texture deceive us; for the comparison of these bodies, which are thus made evident by the disease, and which no doubt pre-existed, with the known lymphatic glands, and which are then found equally swelled, proves their perfect identity. All exhibit either the same fatty and white substance, or the same caseous pus, according to the period of the disease.

In general these glands are much developed in childhood, diminish in the adult, and almost disappear in old age. They are, it appears to me, a little more evident in women than in men, in the phlegmatic temperaments than in the sanguine. Of all the different enlargements of which they are capable in different places, the tabes mesenterica gives them the greatest size.

Their form, sometimes oval, sometimes more or less elongated, always tending to a round one, which is generally that to which all the organs of animals, and even all those of organized bodies are disposed; whilst those of inorganic bodies assume those of cubes, prisms, &c.

The lymphatic glands, sometimes insulated as in the extremities of the limbs, collect in greater number as they approach their common trunks. The axilla and the groin contain many of them, as I have already said ; but in the abdomen, they are united in a group, and are so close to each other in the mesentery, that they have appeared to Azelli to form in this place, not an union of organs, but a single one, which he has taken for a second pancreas, and to which he has given his name.

II. *Organization.*

The colour of these glands, reddish in childhood, grey in the adult, becomes of a yellowish tinge in old age, and has that subsidence and flaccidity which then characterize almost all the organs. This colour varies also according to the regions ; thus the bronchial glands have a black appearance, inherent in part in their structure, but owing probably also to the fluid that they contain, as the appearance of this fluid proves, when it is pressed out of a divided gland. This colour does not depend on its proximity to the lungs and on their colour, though we know, they have many black spots upon them ; the proof of this is, that I have already very often found the lumbar, mesenteric glands, &c. also black. Yet there is no part in which this colour would be more common than around the lungs. Cruikshank, in order to prove the passage of the lymphatics through the glands, says that he has found those in the neighbourhood of the liver yellow in jaundice, in which it is very probable that there is absorption of bile. But this remark is unimportant, since all the parts of the body, without exception, exhibit, in this affection, this colour, which is only a little more evident in the cellular parts.

We cannot deny however but that these glands often take a colour similar to that of the fluid which fills the absorbents, either in a natural state, or in injections, on

account of the great number of vascular divisions that penetrate them internally. During digestion, at the moment the lacteals are transmitting chyle, the mesenteric vessels become almost as white as this fluid, and soon lose this colour when the transmission is finished. By filling the absorbent system with mercury, the same phenomenon is observed.

Common Parts.

The structure of the lymphatic glands, considered in its common parts, is as follows; a very abundant, extensible, loose cellular texture surrounds them, allows them to be moved and easily displaced by the finger when pushed against them. Hence the remarkable mobility of most of these organs, in the first periods of their swelling; in which this texture does not then participate; for it is gradually affected, loses its laxity, and then adhesion succeeds to mobility. Thus in cancer, the glands are first rolling, and afterwards become fixed. In acute inflammations, they are in general fixed, because the neighbouring texture partakes almost always of the disease.

The cellular texture forms besides around the glands a thick membrane which more immediately envelops them, and which deprived of fat and serum, exhibits the nature of the cellular covering of the absorbents. It is this last membrane which, in the ordinary state, gives to the glands an appearance in general smooth and polished; for mercurial injections develop in them some roughness, owing to the prominence of the vessels that run through them in the interior. Some slight depressions are also visible on their surface; they are to these glands, what the furrows on their concave face, are to the liver, the spleen and the lungs; it is through them that the vessels enter. We might think that the arteries were very numerous in the lymphatic glands, if we judged

from injections which colour the whole of them, if they are fine and adroitly used; but little reliance should be placed upon this. Simple inspection, in a living animal, which is infinitely more certain, does not discover much blood in these glands. In the fœtus and in childhood, the quantity of this fluid is much more considerable; hence in part the redness that characterizes these organs at this period of life. We are ignorant whether nerves exist in them, and whether any of the numerous branches that the ganglions send in their neighbourhood, especially in the mesentery, are introduced into their texture; I have never traced any of them there.

Peculiar Texture.

The peculiar substance of the lymphatic glands exhibits a pulp very analogous to that of the nervous ganglions. No fibre can be distinguished in them. Soft in the fœtus, withered in the few glands that remain in old age, this substance, is particularly altered, as I shall say, by scrophulous diseases, and by the influence of the affections of the neighbouring organs.

This peculiar texture has a greater or less density. We find it more solid, and resisting better the injection of mercury in the superficial glands than in the deep-seated. They have cells at short distances, especially in childhood; they contain a whitish fluid, which disappears as well as the cells themselves, at an advanced age. This fluid, of a very peculiar nature, can only be compared with those of the thyroid and thymus glands, which, like this, are found as it were extravasated, in the interstices of the organs that separate them, they have no reservoirs, and their use is wholly unknown. There is no doubt that the great quantity of blood that enters the lymphatic glands in childhood, is owing to the superabundance of this fluid. Sometimes in the adult, there is a great quantity of it in the bronchial glands, where it is

of a blackish colour. Some physiologists have thought, without anatomical proof, that it is spread out upon the bronchiæ, and that it forms in part the black spittle that is thrown out in the morning. Fourcroy in particular is of this opinion; he attaches importance to the black colour of these glands, which are perhaps, according to him, the reservoir of the carbonaceous matter of the blood. The fact is, they belong to the lymphatic system; that in a great number of subjects they are grey or red; that we do not know that they have an excretory; that their texture is pulpy like that of the analogous glands; and that their size distinguishes them however from all others. I have observed that the acids, the alkalis and stewing, alter but little their black colour and that of the fluid contained in them.

It is in the peculiar texture of the lymphatic glands that the absorbents ramify, after being introduced there in a certain number, and each with numerous ramifications, and afterwards go out by many other branches which also give rise to an infinity of smaller ones. Each gland may in this respect be considered as the centre of two small opposite capillary systems, which anastomose with each other. In the interior of these glands, these branches very tortuous, folded upon themselves in different ways, occupy a great part of the peculiar texture of these organs which many thought in consequence were nothing but an interlacing of the absorbents; an idea that is not proved, since this texture is not yet well known.

I have observed that it is susceptible of less horny hardening than most of the other animal textures. It approximates in this respect that of the true glands; but it differs in this, that instead of continuing to harden by long continued boiling, it soon softens, becomes pulpy, and breaks with great ease under the finger. The acids after having crisped it, dissolve it also more easily than many of the other textures; the sulphuric and muriatic

are remarkable for this. Exposed to the action of the alkalis, it loses some of its principles, which weaken these menstrua; but it is never entirely dissolved.

ARTICLE THIRD.

PROPERTIES OF THE ABSORBENT SYSTEM.

We shall consider in the same article the properties of the absorbent vessels and those of their glands.

I. *Properties of Texture.*

Extensibility of texture exists in the absorbent system. 1st. The thoracic duct is distended in an evident manner by injection, before the rupture of its peculiar membrane takes place. 2d. I have said that the absorbents examined around the serous membranes in a living animal, principally in the liver, often exhibit little bladders or considerable dilatations. Are these dilatations varices? is there an analogous character in this respect, between the absorbents and the veins? I know not; whatever they are, they can be very considerable in a long absorbent vessel. 3d. When we tie the thoracic duct, not only that swells, but the lymphatic vessels of the abdomen also dilate, and this ligature is the most convenient means of observing the lacteals. This extension has undoubtedly limits; carried too far, it would probably produce in a natural state the rupture of the vessels, as happens from injections. We have not yet any data founded upon observation or experiment, respecting this rupture, though some authors have endeavoured to explain by it the formation of most dropsies.

Contractility of texture is evident in the absorbent system. 1st. When the thoracic duct is distended even

in a recent dead body, and the fluid is discharged by puncture, it immediately contracts. 2d. All the absorbents contract also as soon as there is no more fluid in their cavity. This phenomenon is remarkable during the absorption of chyle ; when that is finished, these vessels evidently disappear by the effect of this contraction. 3d. The absorbent glands, swelled at the moment chyle is passing through them, afterwards lose much of their size by this contractile power.

II. *Vital Properties.*

We have but few data concerning the animal properties of the absorbents. Sensibility of relation does not appear to exist in them ; it is difficult to ascertain this by experiments. When we puncture a lacteal when it is full of chyle, a lymphatic filled with serum on the surface of the liver or even the thoracic duct, the animal gives no indication of pain. But what inference can be drawn under circumstances, in which the abdomen being opened, the numerous painful sensations would render nothing, comparatively, the slight sensation which the puncture produced, admitting that it existed ? No experiment, I believe, has yet been attempted to ascertain if irritation carried to the interior of these vessels produces a sensible effect. Probably the same result would be obtained by fine injections used for this purpose, as has been for the veins, considering the analogy of structure and the continuity of the peculiar membrane of both systems.

There are circumstances however in which the absorbents have a very acute sensibility, viz. when they are inflamed. It is a very frequent phenomenon in diseases, that there is a very evident swelling and redness, along the course of the sub-cutaneous absorbents in the lower extremities, giving considerable pain to the patient, terminating at the inguinal glands, or even extending beyond. In wounds with a poisoned instrument, in the acute pains

of a whitlow, &c. a very painful sensation is often felt the whole length of the absorbents of the superior extremities.

The lymphatic glands do not appear to enjoy, in a natural state, animal sensibility, when they are irritated in different ways, which can easily be done. But inflammation may develop it in these glands as in the absorbents, by raising to a high degree their organic sensibility. Thus the pain is very acute, when after a puncture made by an infected instrument, after a sprain, &c. these glands swell. We know the extreme suffering that arises from those in the axilla, when they swell and suppuration succeeds. Shall I speak of the pains experienced from the mesenteric glands when cancerous? Who is ignorant of those which buboes occasion, &c.?

As to animal contractility, it is entirely wanting in the absorbents and their glands.

The organic properties exhibit in the absorbent system, the following arrangement. Sensible contractility has been allowed them by Haller. It is founded upon this, that the lymphatics easily empty themselves of the chyle that passes through them, and upon this also, that by touching them with sulphuric acid, they crisp immediately. But sulphuric acid, like all the concentrated acids and caloric, produces the same effect upon all animal substances, even after death; it is the horny hardening. When the absorbents, particularly the thoracic duct are touched with the point of a scalpel, no contraction follows. If they are capable of contracting upon themselves, it appears that it is when they cease to be distended, and not when they are irritated; and that it is consequently by their contractility of texture. The sensible organic contractility is then at least doubtful in them, if it exists it is very obscure and at most to be compared to that of the dartos muscle.

The organic sensibility and the insensible organic contractility are evidently found in the absorbents. It is by

these properties that they perform their functions, that fluids are absorbed by them, that they circulate in their branches, &c. &c. These two properties are remarkable in them in this, that they continue some time after death. A fluid injected when the animal is still warm, is absorbed, either on the serous or mucous surfaces. It is less easy in the cellular texture. We can prolong a little this absorbent power, by supporting the heat artificially by a bath. This has in general less efficacy than I thought for a long time. Various recent experiments have convinced me of this. This arises no doubt from the fact, that it is the vital heat and not an artificial one, which is necessary to the exercise of this function, or rather vital heat and absorption are two effects of a common cause, viz. organic properties. As long as these properties remain in the solids, they retain caloric and absorb. But the moment they are gone, the heat goes and at the same time absorption ceases. It would be useless to expose to caloric, solids that life had entirely abandoned; they would become warm; but they could exhibit no vital phenomenon. In the same way it would be useless to keep up the heat of an animal recently killed, by making an artificial one succeed the natural. It is organic sensibility and insensible contractility, that must be prevented from escaping to prolong absorption. If artificial heat keeps up this function, it is only by first keeping up these properties. We cannot calculate upon absorption when the animal is cold, though Mascagni and many others have said otherwise. I have in vain attempted to keep it in action then; generally I have not observed it above two hours after death. The organic sensibility is in relation with many fluids in the absorbent system, and it is in this that it differs from the other systems, the glandular, for example, which is never in relation but with one particular fluid, and which rejects all the others in a natural state. Water and other

mild fluids can easily be absorbed, though very different from the lymph. In the natural state, the thoracic duct alternately admits chyle and lymph.

Character of the Vital Properties.

From what has been said, it is evident that the organic properties perform the principal part in the peculiar life of the absorbent system. These properties are much more conspicuous there than in the venous system; at least they are much more capable of being raised. In fact there are ten inflammations of the absorbents for one of the veins. This disposition to inflame from the least virus that passes through their tubes, from pains, though not severe, that are felt at their extremity, particularly characterizes these vessels. It is rare that there is found in the course of a vein, those swellings, pains and inflammations so frequent in the course of the absorbents. This difference proves a diversity of structure in the peculiar membrane, notwithstanding its continuity with that of the veins. In fact at the period when experiments were made upon the transfusion of medicines into them, authors have not related any case of venous inflammation from the contact of foreign substances upon the membrane of the veins; whilst practice frequently presents us this fact in the absorbents.

The lymphatic glands especially have a great tendency to inflammatory swellings, when deleterious substances that are absorbed come in contact with them. In the first periods these substances confine their effects to the first glands they meet; thus the absorption of the venereal virus hardly extends beyond the glands of the groin; thus the axillaries alone swell when a puncture is made with an infected instrument, &c.; the glands that follow, remain untouched.

Though much disposed to inflame, the lymphatic glands exhibit however more slowness in this affection, than many

other animal textures, the cellular and cutaneous, for example. We know that phlegmon and erysipelas go through their periods quicker, than the inflammations of the inguinal, axillary glands, &c. The pain of which these inflamed glands are the seat differs also much from that of these two affections; it is more dull, obscure, &c. The pus is more slow in forming; it resembles considerably cellular pus; it differs much from that of erysipelas. There are few textures in the economy that are more disposed than this to hardening after inflammation. For one single time that the skin become scirrhous after erysipelas, the lymphatic glands become so twenty. This is truly one of their distinctive characters.

The absorbents often exhibit to a certain degree, like their glands, a character of slowness in the phenomena over which their organic properties preside. For example, when concerned in a wound, they contract, crisp up and close more slowly than the sanguineous capillaries, that are then also concerned; hence the flow of serum that continues for some minutes after that of blood has ceased. This phenomenon is constant in small wounds. If the absorbents and the capillaries had the same degree of insensible contractility, it certainly would not take place.

Here then are new proofs of the principles of which we have every instant occasion to present the consequences in this work; viz. that the vitality peculiar to each system, the particular degree of vital forces that characterize them, imprint upon all its affections a peculiar tinge and aspect, if I may so express myself, unknown to all the other systems.

Differences of the Vital Properties in the Absorbent Vessels and their Glands.

Though we have considered at the same time the vital properties in the glands and in the absorbents, though

anatomy shows the first to be an assemblage of folds and vascular windings, yet it cannot be denied that they have a peculiar kind of vitality, by which they are distinguished from the absorbents that come to them. It is this peculiar kind that exposes them to certain diseases of which the absorbents are not the seat, at least not in so evident a manner. The scrophulous virus seems more especially to attack them. They are particularly affected in tabes mesenterica, strumous diseases, &c. In the innumerable swellings of which they are the seat in consequence of organic diseases, the absorbents do not appear at the same time altered in their texture. It seems even that in a very great number of cases, the numerous folds that these vessels form in the glands, do not partake of their organic injury; they, in fact, transmit the lymph as usual. Nothing is more common than to see abdominal and thoracic enlargements of these glands in children, without producing serous effusions, even at the most advanced periods. In opening the bodies of small subjects, I have often been astonished at this phenomenon. The lymphatic vessels are not even more dilated, at least we do not find them easier in children affected with tabes mesenterica, than in others. We can hardly ever discover them at this age to inject.

Sympathies.

The absorbent system is much disposed to receive the sympathetic influence of the other organs. This disposition relates, 1st, to the glands; 2d, to the vessels themselves.

One of the phenomena which the examination of dead bodies perhaps most often exhibits, is the swelling of the lymphatic glands from the organic affections of the principal viscera. We observe this phenomenon, 1st, in the neck from the affections of the thyroid gland and sometimes of the larynx, in the jugular glands; 2d, on the

chest from cancer in the breast, in the axillary and often in the mammary glands, from every kind of phthisis in those that surround the bronchiæ, very rarely if ever from diseases of the heart, whether aneurism, ossification or diseases of the valves; 3d, in the abdomen, from cancerous diseases of the stomach, especially of the pylorus, and most of those in which the texture of the liver is altered, in the numerous glands that accompany the biliary vessels and those surrounding the pancreas; from schirrus of the intestines, from their cancers, which are in general rather rare, in the mesenteric glands; from the affections of the womb, the rectum, and the bladder, in the glands of the pelvis; from schirrus of the testicles, diseases of the urethra, in the inguinal and lumbar glands, &c.; 4th, on the superior extremities from punctures, bites and most of the inflammatory affections in the axillary glands; 5th, on the inferior extremities from many affections in the inguinal glands.

These swellings of the lymphatic glands are of the same nature as the affection that produces them; if that is acute they are so, if chronic they pursue the same course. The swelling of the glands in the axilla is acute, if it is the consequence of a prick of the finger, of a whitlow, &c. and chronic, if it arises from cancer.

I am far from considering all these different swellings as the result of a sympathetic influence exerted upon the gland. No doubt the conveyance of absorbed matter produces the effect, as happens when there is some virus, punctures with poisoned instruments, &c. producing the swelling. But sometimes also sympathy alone is the cause. When by the acute pain that a whitlow, a splinter under the nail or a bruise of the finger occasion, the axillary glands swell; when the same glands swell from the effect of a blister applied to the arm or fore-arm, &c.; when this phenomenon happens in the inguinal glands from a blister on the thigh or the leg, of which I have

seen many cases, &c. &c. there is certainly no matter conveyed to the gland; it is an effect of sympathy.

Most surgeons believe that every cancer in the breast, with swelled glands, requires their extirpation. I believe that in some cases they may become cancerous, but I doubt if this happens in the greatest number. 1st. In old ulcerated cancers of the breast, they continue most often swelled during the whole of life, without suppurating. 2d. After operations, in which some deep seated ones have been left, we rarely see them become cancerous. When the cancer is reproduced, it is the wound that opens again. 3d. I have many times compared the texture of a gland of the axilla enlarged by a cancer of the breast, with that of the bronchial glands enlarged in phthisis, with that of the sub-hepatic glands swollen from steatomatous tumours, hydatids of the liver, &c. and I could discover no difference. 4th. Finally, all those who open many dead bodies may be convinced that almost all the organic diseases of the viscera which have many glands around them, are accompanied with their enlargement, whatever may be the nature of those diseases. This phenomenon struck me so much, that at one time attributed the effusions which terminate almost all these organic diseases, to the difficulty the lymph experiences in passing through these glands. But the absence of these swellings in the diseases of the heart attended with dropsy, the frequent absence of swelling of the superior extremities when the axillary glands were enlarged, the tumefaction of the lower parts, the glands of the superior being alone swelled, and many other similar proofs, which made me consider the serous effusions that take place then, as passive exhalations, analogous to those that produce hemorrhages, did not permit me to adopt this first opinion.

It is essential to distinguish the swellings of the lymphatic glands by the influence of the diseases of the

neighbouring viscera, from those which arise from tabes mesenterica and other analogous, scrophulous diseases. 1st. In the latter case, the texture of the gland is always primarily affected; it is only secondarily in the other. 2d. The one from scrophulous affections appears exclusively in childhood; the other at all ages. 3d. Finally, a gland swollen from the affection of another organ, most frequently preserves a texture, and colour analogous to its natural state. It is only in the last periods that the texture becomes sometimes hard, like cartilage, and even suppurates; but it is not with the same phenomena as the texture of the mesenteric and bronchial glands swollen by scrophula. The appearance and structure are wholly different. This last exhibits in this case a white substance which is found in small quantity in the first periods; so that when we cut the gland, we easily distinguish this substance from the texture of the gland that remains, where it still exists, with its natural colour and arrangement. In the latter periods, this white matter has encroached upon the whole gland, the texture of which has disappeared. However in phthisis, and sometimes, though more rarely, in cancers, the swelled glands exhibit in consequence an analogous appearance; but in all the other cases it is different.

We know that nature often chooses these glands in important fevers, as the place of the crisis. They are the seat of what are very improperly called parotid tumours, in adynamic fevers.

The absorbents are, like their glands, influenced by the affections of the neighbouring organs. I am well persuaded that the different alterations which the absorption of chyle undergoes, the absorption of the aqueous part of the bile and the urine, and the derangement of those of the serous surfaces in many diseases, are effects purely sympathetic. But it is not very easy to distinguish when they are not so. There are certainly sympa-

thetic absorptions, as there are sympathetic exhalations and secretions.

On the other hand, the absorbent system being affected, the other organs very often experience sympathetic influences. In tabes mesenterica, and in the enlargement of the bronchial glands that correspond with it, there are many symptoms that evidently arise from the sympathetic relations that connect these glands to the other organs. It is not my province to point out these symptoms.

As to the influence of the diseases of the absorbents upon the other organs, we know but little of it. When their course is inflamed from a puncture, from a wound with an instrument having on it some virus, &c. there are often vomitings, diarrhoea, &c.

ARTICLE FOURTH.

OF ABSORPTION.

I. *Influence of the Vital Forces upon this Function.*

THE functions of the absorbents are not at the present day a subject of doubt with any anatomist; but the manner in which these functions are performed, are far from being so well agreed upon. The first idea has been to compare the action of the absorbents with that of capillary tubes. But if we reflect a little upon this action, it is easy to see that these phenomena are wholly different from those of inert, capillary tubes. I think that we never should be able to say precisely, how an absorbent orifice, being immersed in a fluid, takes it up, seizes its particles and makes them ascend in its tube. But what is undoubted in absorption is that the vessels derive this faculty from the vital forces which they have:

that it is only the relation existing between the particular kind of organic sensibility with which they are endowed, and the fluids with which they are in contact, that is the immediate cause of the phenomenon. Do you wish numerous proofs of this? See the lacteals choosing only chyle from among the variety of matter contained in the intestinal canal; see the absorbents of the bladder and the gall-bladder leaving many of the elements of the urine and the bile, to take only the aqueous part of these fluids; see the cutaneous absorbents, the mucous ones of the bronchiæ, &c. selecting only certain principles from the air and leaving others. Often inactive for a long time, they immediately recommence action when any substances in relation with their sensibility are presented to them. Observe the fluids injected or effused into the cellular texture, they are taken up or left by the absorbents of this texture, disappear promptly, or remain and occasion suppuration, according as they agree with or are repugnant to their sensibility.

We cannot deny that in the natural state the sensibility of the absorbents has a particular type, to which certain substances are alone accommodated, and which alone on this account can be absorbed. The exercise of the organic sensibility then always pre-exists in absorption, as it does in secretion, nutrition, &c. Thus in the physical phenomena, the exercise of gravity always precedes the fall of heavy bodies. Thus the power of attracting is put into exercise before the motion of the planets takes place, &c. &c.

II. *Varieties of Absorption.*

It follows from what I have said, that whenever the organic sensibility of the absorbents is altered in any way, absorption must necessarily experience a corresponding derangement; now this is what constantly happens. Serum often bathes for whole months the ab-

sorbent orifices, in dropsy, without raising their sensibility sufficiently to be taken up by them. Let any cause increase this property, instantly absorption takes place. Observe some indolent tumours which remain for a long time in the same state by the stagnation of their fluids, they are immediately discussed when certain medicines applied to them rouse the dormant sensibility of their absorbents. Discutients do not act upon the fluids themselves; they do not attenuate, or cut them, according to the vague language of physicians, but by changing the degree of force of the absorbents, they render them able to act. It is so true that it is in this way that different resolutions are effected, that often a slight degree of inflammation is previously necessary to their development; all surgeons know this. Desault did not consider most of the swellings of the testicles as an obstacle to the operation for hydrocele by injection. On the contrary it often happened, that after the irritation produced in the testicles by the surrounding membrane, the enlargement disappeared, which was only kept up by the want of energy in the absorbents.

The alterations of organic sensibility can diminish, increase, or variously modify this property. Let us cease to wonder then at the extreme variety of the absorptions; let us not be astonished, if many fluids, besides those ordinarily taken up, can pass into the blood by the absorbents; if the bile, the urine, the mucous fluids, which are usually rejected, can enter the circulation; if the blood effused in the cellular texture is taken up by these vessels. The forces of life impress, by their extreme variety, the same character on all the functions over which they preside.

Much has been said of putrid matters passing into the blood, and there serving as a cause for diseases. This infection of the blood has undoubtedly been exaggerated; but I am convinced that in many cases it is real. Why

are the colour, consistence, odour, and nature of the excrements so very variable? If the same substances are always absorbed from the aliments, it is evident that the residue of these aliments would always be the same. Observe the innumerable varieties of the urine, the bile, the mucous fluids, &c. according to the difference of the principles that concur to form them. Why should not the chyle present the same variations? it would be the only fluid of its kind in the animal economy if it did not change under many circumstances. Now, whence can these changes come, if not from this, that the lacteals present numberless varieties in their organic sensibility, varieties, each of which admits only certain principles and rejects the others?

The absorption of the lacteals, which, in an ordinary state, introduces into the blood only nutritive substances, can then often be a way open for the admission of many morbific principles. Thus in the lungs, the vessels which take from the air the substances proper to colour the blood, often draw in principles injurious to their functions, according to the different alterations that their sensibility can experience.

In the ordinary state, the kind of organic sensibility and of tone of the cutaneous and mucous absorbents, shuts out all external substances that are hurtful. But when this kind is changed, the way can in an instant be open to them. Does not pus remain without mischief on the cellular texture, in most wounds? Let an imprudent application raise there a little the forces of the absorbents, it is taken up by them; the ulcer dries up; the pus passes into the blood; and then follows the whole sad train of the symptoms of re-absorption which commences.

We can say, that a thousand channels are incessantly open in our organs, to morbific principles. The organic sensibility, placed as a sentinel at their mouths, indicates

according to the manner in which it is affected, to the insensible contractility when it is necessary to open or shut them.

It is exhalation that contributes to the formation of most tumours; it is absorption that serves for their cure.

If I were to run over the phenomena of absorption in the different ages, sexes, seasons and climates, I could show constantly the differences of organic sensibility always preceding the differences of this function. I shall speak of them in the different ages.

The causes that vary the natural type of the sensibility of the absorbents, are, as in all the other functions, direct or sympathetic; 1st, direct, as when by previous friction on the skin, we excite the absorbents, and force them to act, which they would not have done without this; 2d, sympathetic, as when the absorbents, feeling the affection of a distant viscus, increase or diminish their action, according to the kind of influence they receive. We have spoken of this phenomenon in the sympathies of the different systems.

III. *Motion of the Fluids in the Absorbents.*

The fluids once absorbed on the different surfaces of which we have spoken, are carried by a successive motion to the common trunks, which transmit them to the black blood.

We know not the laws of this motion. It is evident from many observations formerly made, that it has much analogy with the motion of the venous blood; but it is also distinguished from it by some differences.

It appears to be in general more slow. The thoracic duct opened when it is full of chyle, does not throw out its fluid as far as a vein of the same size.

The motion of the lymph does not seem to be subject to a reflux in the neighbourhood of the heart, like the venous blood. For example, the venæ cavæ, jugulars,

&c. are so much the more dilated, in proportion to the obstacles the lungs have opposed to the return of the blood. Now in injecting the thoracic duct, I have never observed between its dilatation and contraction, and the state of the pulmonary organ, any kind of relation. On the other hand, we never find this duct full of lymph, as we find the veins full of blood, when an obstacle has interrupted the motions of the fluid in the last moments.

How happens it, that in the reflux that produces the venous pulse of the jugulars, the blood does not enter into either absorbent trunk ? The valves, arranged to prevent the entrance of that, which in a natural state, flows towards the heart, are evidently useless here. We can clearly attribute this phenomenon only to the relation existing between the orifice of these trunks and the black blood, as the orifice of the larynx, foreign by its vitality to external bodies, repulses every fluid but the air. Blood is never found in the thoracic duct.

There is in the venous blood an evident continuity of motion, from the capillary system to the heart ; it is from this system that it goes, to be propagated, if we may so say, to that organ. The motion of the lymph, on the contrary, is incessantly interrupted by glands, each of which, as I have said, exhibits really in relation to the vessels that enter and go out of it, a small capillary system. At each gland the motion necessarily changes its impulse ; now as the state of these glands is susceptible of many varieties, we can easily conceive, that the motion of the fluids circulating in the absorbent system, necessarily presents a great number of them ; that it may be rapid in one part, very slow in another, regular here, there irregular, &c. Hence we must not be surprised if we find some absorbent vessels dilated, whilst those of the neighbourhood are hardly perceptible. There is indeed a kind of variety in the veins, but it always has its

source in the origin of these vessels, and never in their course, as takes place in the absorbents.

The continuity of the venous blood and the frequent interruptions of the lymph should establish differences not only between the motions of the two kinds of vessels, but also in the composition of the fluids. The first is necessarily everywhere the same; the second may vary at every gland, and take new modifications at each of those through which it passes.

I should be disposed to think that the insensible contraction of which the small capillary system of each gland is capable, would aid the motion of the lymph, by diminishing the course that this fluid must take, without a new impulse, from the origin of the absorbents to the black blood, if these organs were wanting. In fact, we know that in the extremities where there are much fewer glands, there are more frequent effusions than in the trunk where the absorbents pass through them at every instant; I speak of those effusions which ought evidently to be attributed to the want of circulation of the lymph, as those arising from compression, too long standing, &c., and not those that depend on an increased exhalation, like those after organic affections.

We see, from what I have said thus far, that we have only a few disconnected views upon the motion of the lymph; that of the veins, though still requiring much research, is yet more known; but in order to give a perfect knowledge of these subjects, the first especially, many experiments and much further labour are necessary.

IV. *Of Absorption in the different Ages.*

In the fœtus and in childhood, absorption relative to nutrition is not in proportion to exhalation. Many substances remain in the organs, but few go out, hence there is growth.

But little is known of the differences which the internal absorptions of synovia, serum, fat, marrow, &c. then present.

The external absorptions appear to be more active, for we know that contagions are taken with much more facility in the first age. We know not however whether the skin and mucous surfaces then constantly introduce more foreign substances into the body, or if they are only more disposed to introduce them.

We are deficient in positive data as to the state in which absorption is found in childhood. To judge of it however by that of the lymphatic glands, it would appear that it was very energetic. In fact these glands are in proportion much developed ; they appear to be the seat of very active functions ; they have a peculiar life more developed than afterwards, hence a greater disposition to diseases. We know that until puberty, or rather until the end of growth, they are the seat of many affections which entirely disappear after that age, and lessen the numerous series of those to which we are exposed.

This double circumstance, 1st, the precocious and proportionably great development of the lymphatic glands in childhood ; 2d, their very great disposition to diseases, indicates certainly remarkable activity in their functions ; for it supposes a great development of the vital forces ; now these vital forces being more developed ought necessarily to preside over more energetic functions. See in fact the organs whose functions we know, which are on the one hand much developed in childhood, and on the other much disposed to diseases ; the functions of these organs are more active. Thus the brain and nerves being more developed, have more sensibility ; thus the vessels with red blood have an activity of nutrition, in proportion to their size, &c. In youth, it is when the genital organs are more developed and they become more exposed to diseases, that their functions are greater. Examine all the

organs and their functions, you will see that a general law of the economy is, that these three things, 1st, great development; 2d, greater disposition to diseases; 3d, greater activity of functions, are constantly united. Now when these two first exist in the glands of the absorbents, we ought to conclude that the third is there also, though we are not certain of it, since, from what I have said, we are ignorant of the uses of these small organs. Grimaud has considered them, it is true, as essential to nutrition; he even calls the nutritive system the combination of these glands and the cellular texture, a gratuitous supposition, which is not proved. All that we know upon this point, is that on the one hand nutrition, and the development of these glands on the other, are very great in the fœtus. But does it follow from this, that the first phenomenon proceeds from the second? Undoubtedly not; no more than because the brain, the liver, &c. are early developed in the fœtus, and nutrition is very active, they should be considered as the agents of this function. Besides, nutrition is a function that has no particular organ for its centre and agent. Each organ is itself the machine which separates from the blood or the fluids that enter it, the nutritive materials that are suitable for it, and afterwards appropriate them to itself. The muscle separates its fibrin, the bone its phosphate of lime, &c. But one common and central organ does not elaborate these nutritive materials, as one common viscus moves the blood, as one central organ presides over sensibility, &c.

As to the anatomical state of the absorbents in the fœtus and childhood, we can know but little; I do not know that any author has injected them comparatively in this age and in the adult. I have but one fact upon this point, it is that the lacteals, examined in an experiment upon two young dogs, who had only left off sucking eight days, appeared to me larger in proportion than at a more advanced age. I will make one remark that

has often struck me; it is that the size of the animal has much less influence than would be thought upon the diameter of these vessels. For example, an adult dog, twice as large as another, has not by a great deal, vessels of double size. Accident led me to examine them the same day, three years since, upon two large grey-hounds, that were among the dogs brought to me, and upon one of those vulgarly called cur dogs; they were nearly equal in all three; this struck me.

We know but little of the different revolutions that absorption undergoes in the ages that succeed infancy. Only there is no doubt that puberty is the limit of this kind of predominance which the lymphatic glands enjoyed in the economy. The age of their diseases is then passed; often even these diseases, heretofore beyond the reach of art, are spontaneously cured. The predominance of the genital organs which succeeds to this and some others, those of the sensitive organs, &c. seems to destroy the germ which this first supported.

Soemmering has described in a particular work the part that the absorbents perform in the different diseases of the adult and the other ages. This part has appeared to me to be often very difficult to be known, notwithstanding what he has said of it. I refer however to his work on this point.

In old age, nutritive absorption continues very active; for it is that which decomposes the body, which takes from it the substances that nourish it, and which consequently withers and dries the organs.

The external absorptions, on the contrary, are feeble; the skin takes with great difficulty the different contagions, as I shall say in treating of this organ; the mucous surfaces absorb slowly; but little chyle passes into the blood in proportion to what enters it in the adult. The two absorptions, the nutritive and the external, are exactly reversed at the two extreme ages of life; the

second is superior to the first in infancy, the first predominates in old age.

As to the internal absorptions, as those of synovia, of the serous surfaces, of the cellular texture, &c. I should think that they predominated in old age, and that to this was to be attributed the numerous serous effusions which happen at that age, and which we observe in dead bodies. We have not however upon this point so good data as upon the other two.

V. *Preternatural Absorption.*

We can understand two things by this expression; 1st, the absorption of fluids different from those naturally taken by the absorbents, as that of effused blood, &c. I have already spoken of this absorption; 2d, that which takes place in the cysts which are developed contrary to the natural order in the economy. Now this last exhibits a very singular phenomenon, when compared with preternatural exhalation. It, in fact, takes place with difficulty; it is rare that you see the fluids of encysted tumours enter suddenly the circulation by absorption, either in whole or in part, as this very often happens in the serous collections of the peritoneum, which, without being cured, have many alterations of increase and diminution. What physician has not observed that the urine flows more as the abdomen becomes flat, and that it is suppressed when it is filled?

Observe on the contrary, that exhalation is renewed with great facility in encysted tumours; that if we empty them and do not remove their cysts, they are soon reproduced, as I have said. Is it that the absorbents are not developed in proportion to the exhalants in these tumours? I know not; but the fact is not less certain; observation of diseases proves it every day.

SYSTEMS PECULIAR TO CERTAIN APPARATUS.

GENERAL OBSERVATIONS.

THE former part of this work has been devoted to researches upon the systems common to the structure of all the apparatus, upon the primitive systems, which form if we may so say the nutritive parenchyma, the basis of all the organs, since there is hardly any one of these organs in which the arteries, the veins, the exhalants, the absorbents, the nerves and the cellular texture do not enter as a more or less essential part. Each is at first a texture of these common parts, then of other peculiar parts which particularly characterize them.

The systems that will now be examined are not so generally extensive in the animal economy. They belong only to some particular apparatus; thus the osseous, the animal muscular, cartilaginous, and fibrous systems are especially destined to the apparatus of locomotion; thus the serous, mucous, and organic muscular systems enter especially into the digestive, respiratory and circulatory apparatus; thus the glandular system forms the apparatus of secretions, thus the cutaneous system enters principally into the external, sensitive apparatus, &c.

All the systems that remain to be examined are then much more insulated, perform a much less extensive part than those of which we have been treating. Confined to certain apparatus, they are unknown to the others, and have an independent life of their own, whereas the primitive systems everywhere mingle their vitality with that of the other organs, into whose composition they enter ; most of them have a kind of existence and external forms which distinguish them from these last. The different parts which compose each, are almost always insulated, not connected with each other ; the bones, the muscles of animal and organic life, the cartilages, the fibro-cartilages, the medullary organs, the glands, the serous membranes, the hair, &c. exhibit this insulation in a remarkable manner. Each portion belonging to these different systems, has always between it and the other portions of the same system many intermediate organs, which are of a very different nature, and which consequently belong to other systems. There are hardly any except the cutaneous, fibrous and mucous systems, which are everywhere continuous in their different parts ; yet this last has no communication between that portion of it which is spread upon the digestive and respiratory apparatus, and that which belongs to the urinary and genital organs.

We have seen on the contrary that the primitive systems are everywhere continuous, having no interruptions in them. The cellular, the arterial, the venous, the absorbent, the nervous are so arranged, that if it were possible to remove all the organs they enter, and leave them alone, they would form a complete whole, formed differently according to the different systems. The exhalants can also be considered as everywhere connected, as we have seen. Suppose on the contrary that the organs intermediate to the bones, the cartilages, the fibro-cartilages, &c. should be removed, all the parts of these

systems would immediately be separated, and you would not have one continuous whole.

The order to be followed in the examination of these systems is of no importance; we shall place them in the following order, which will comprehend 1st, the osseous; 2d, medullary; 3d, cartilaginous; 4th, fibrous; 5th, fibro-cartilaginous; 6th, animal muscular; 7th, organic muscular; 8th, mucous; 9th, serous; 10th, glandular; 11th, cutaneous; 12th, epidermoid; 13th, and finally, the system of the hair.

Observe that nature is not confined to any methodical order, in distributing these systems in the different apparatus; that she has no regard to the great differences that she has established between the functions. Each can at the same time belong to the apparatus of functions that have no analogy. Thus the fibro-cartilaginous, which is found especially in the organs of locomotion, and consequently in animal life, enters also by the trachea into the respiratory apparatus; thus the mucous system, everywhere destined to the organs of internal life, belongs also to the external life in the conjunctiva, in the nasal fossæ, &c. to generation in the vesiculæ seminales, in the prostate, &c.; thus the glandular system pours by turns fluids upon the organs of the two lives as upon those of generation; thus the serous surfaces are spread upon parts whose functions have no resemblance upon the brain and the stomach, for example, upon the articular cartilages and the lungs, &c. Let us consider then the simple systems abstractedly, if I may so say; let us describe them in an insulated manner as materials distinct from each other, though united two by two, three by three, four by four, &c. to form the partial edifices of our apparatus, edifices from which results the general edifice of our organs. Each of these apparatus is destined to exercise a determinate function, and ought consequently to be classed as functions; it is in this manner also that we shall distribute them in the Descrip-

tive Anatomy. But the simple systems, not tending to a common object, except as they are united in the apparatus, we cannot, when considering them separately, confine them to any classification borrowed from their destination.

OSSEOUS SYSTEM.

THIS system, remarkable among all the others by the hardness and resistance that characterize it, has from this double attribute a fitness to serve as a common base for all, upon which they rest, and around which they are suspended and fixed. The whole of the pieces that form it, are connected together for this use, by means of flexible and resisting bands, which with these pieces make a whole that is called a skeleton. The osseous whole, placed in the midst of many organs that it sustains, everywhere continuous in its different parts, has not however, like the primitive systems, continuity of peculiar life from one of its extremities to the other. The bands which connect these different pieces, very different from them in their nature and their properties, produce in them an insulation of vitality, which the different parts of the above systems do not exhibit, because in their continuity their nature is everywhere the same.

ARTICLE FIRST.

Of the Forms of the Osseous System.

Considered in relation to their forms, the bones are of three sorts, long, flat and short. One dimension predom-

inates in the first, viz. length; two are in nearly equal proportions in the second, length and breadth; these two last dimensions, with thickness especially added, characterize the short bones. Let us examine each in a general manner.

I. *Of the Long Bones.*

The long bones belong in general to the apparatus of locomotion, in which they form a kind of levers that the muscles move in different directions. All are placed in the extremities, in which their whole forms a kind of central column, moveable in different directions. We see them successively diminishing in length and increasing in number, when examined from the superior to the inferior part, from the thigh or the humerus to the phalanges of the toes or the fingers. It follows from this double opposite arrangement, that the top of the limbs is characterized by the extent of its motions, and the bottom by the multiplicity, variety and narrow limits of these motions.

These bones have all an analogous conformation; thick and large at their extremities, they are more slender and usually rounded in the middle or body, as anatomists call it.

The size of the osseous extremities exhibits the double advantage, 1st, of presenting to the articulations large surfaces and consequently more causes of resistance to different displacements; 2d, of contributing to the regularity of the forms of the limb to which they belong. Observe in fact that the muscles and the bones are placed in an inverse direction in the extremities. The middle of the first, which is their largest part, corresponds to the middle of the second, which forms their small portion, whilst the extremities of these compensate by their size for the smallness of the tendons which terminate the others, and which are placed at the side of them. The

increase of size of the extremities of the long bones is not sudden; it commences imperceptibly upon the body. We observe upon these different extremities eminences of articulation and of insertion.

The middle or the body has no eminence; prominent lines are seen there, always destined for aponeurotic insertions, and which, when they are very considerable take from the bone its cylindrical form, which it however preserves in the interior; thus the tibia is evidently triangular externally, though within its canal has the form of that of the femur. In general these lines of insertion, always separated by plain surfaces, are three in number upon each long bone, as we see on the humerus, the radius, the ulna, the tibia, fibula, &c. I know not the reason of this law of conformation. Another general observation is, that the body of almost all the long bones is twisted, so that the direction of its superior part is not the same as that of the inferior; by tracing from above downwards one of these lines of which I have just spoken, this may be seen; it is however more evident in the adult than in the fœtus. This change of direction has no uniformity in the course it pursues.

The internal forms of the long bones are very well seen by sawing them longitudinally. The texture of the cells fills them to the extremities; it is, as we shall see, more fine and less abundant in the middle, where the medullary canal exists.

This canal does not exist in the first month of the fœtus, nor as long as the bone is cartilaginous; the osseous state is the period of its formation. All the gelatine of the middle of the bone is then absorbed, exhalation brings no more there, except in the very delicate texture of the cells that this canal contains; this function, which is nothing in the centre, becomes more active on the circumference of the bone. This increase of activity of the external exhalants favours the formation

of the compact texture, the development of which takes place precisely at the same time as that of the canal whose parietes it forms; so that at this period of ossification, exhalation and absorption appear to be in an inverse state in the two parts of the bone; one is very active on the exterior in bringing phosphate of lime, with which it encrusts the already existing parenchyma; the other is very active in the interior in removing the gelatine whose absence forms the space from which the medullary canal arises.

There is no well marked medullary cavity except in the humerus, the radius, the ulna, the femur, the tibia, the fibula and clavicle. The ribs and the phalanges, which in their forms resemble them, have much of the ordinary texture of the cells in their centre, and hardly ever any of that more delicate texture of the cells which occupies the centre of the bones above named, and which is only found in the medullary cavity.

This cavity does not extend beyond the body of the bone; where the compact texture grows thinner, it disappears, and is replaced by a great quantity of the texture of the cells, which fills the extremity of the bone. Its form is cylindrical and its direction straight. It does not vary in its form, on account of its asperities or the external prominent lines of the body of the bone, which is only thicker in these places. Its parietes are much smoother in the middle, than at the extremities, where there are already many considerable cellular filaments thrown off. There are in many subjects, delicate, horizontal bony partitions, which interrupt almost entirely its continuity in this place, and appear to divide it into two or three very distinct parts.

The medullary canal serves not only to lodge and defend the medullary organ, but also to give more resistance to the bone; for we know, that of two cylinders formed of an equal quantity of matter, one of which is hollow, and

consequently has a greater diameter than the other which is full, the first will resist more than the second, because we can bend and break it with less facility. Full cylinders, equal in diameter to the long bones, would have prevented by their weight, the motions of the limbs; whilst other cylinders of the same weight as the present, but without any cavity, would give too small a surface for the insertion of the muscles. To unite small weight with a sufficient space in the middle of the long bones, is then a great advantage of the medullary canal.

This canal disappears in the first periods of the formation of callus in fractures, because the whole medullary organ is occupied at this place by gelatine, and becomes cartilaginous; then this gelatine gradually re-absorbed, without being replaced, favours the development of a new cavity, and the communication is re-established between the superior and inferior parts of the canal.

I have observed that, in the first age, and while the extremities of the bones are cartilaginous, the medullary canal is shorter in proportion than in the adult; it hardly forms at birth more than the middle third of the bone, the superior and inferior thirds being formed at first by the cartilaginous portion of each extremity, then a texture of cells intermediate between this portion and the canal; so that as we advance in age, its length becomes in proportion greater.

II. *Of the Flat Bones.*

The flat bones have in general, but little relation to locomotion, which they only assist by the insertion of the muscles that go to the long bones. Nature designs them especially to form the cavities, such as those of the cranium and the pelvis. Their conformation renders them very proper for this use. Their number varies according to the cavities with which they are connected; many always unite to form one, and it is this circumstance that

contributes in part to their solidity. In fact, external blows losing their force at the place of their junction, fracture them with less ease. If the cranium was only one single piece, its solutions of continuity would be much more frequent than they now are. So that as the sutures ossify in old age, they become more brittle. In children, in whom the ossification is not complete, and the number of whose separate, osseous pieces is consequently more considerable in the head, the pelvis, &c. the difficulty of fractures is very great, because the soft bands which unite the solid parts yield to external bodies, without breaking.

The flat bones are almost all curved, concave and convex on the opposite sides; this arises from their destination in the formation of cavities. Their curve varies according to the place in the cavity they occupy; this curve is the cause of a very powerful resistance, when that mentioned above does not exist. Thus in the first age, the cranium resists by yielding; but as the sutures become more closed, and only one osseous piece is formed, it is by the mechanism of the arch that the brain is protected.

All the flat bones have two surfaces and a circumference. According as the first serve for muscular insertions, or are only covered by aponeuroses, membranes, &c. they are rough or smooth. Towards the middle the bone is thinner; it has more thickness at the circumference, which is either for articulation or insertion. In the first case, this excess of thickness gives more solidity to the joints, which are then made with larger surfaces, as we see in the cranium; in the second, it presents to the fibres more points of origin, as we see on the crista of the ilium and the greater part of its circumference.

The internal forms of the flat bones have but few peculiarities; their two external layers leave between them a space which is filled by the texture of the cells.

III. *Of the Short Bones.*

The short bones are placed in general in parts where are found united mobility and solidity, as in the vertebral column, the tarsus, and the metatarsus. Always small, they are in great number in the regions which they occupy ; their number compensates for their size in the formation of the parts of the skeleton to which they contribute. It is this number also, that gives to these parts the union of the two almost opposite attributes of which we have spoken, viz. solidity, because the external efforts are lost in the numerous bands which unite them, and mobility, because the whole of their individual motions gives a considerable general motion.

There is nothing constant or uniform in the external conformation of these bones ; it is modified according to the general plan of the whole, of which they are the parts ; thus the different uses of the carpus, metacarpus and vertebral column determine the different forms of their respective bones. These bones have always many cavities and eminences upon their external surfaces, necessary for their numerous articulations, for the insertion of the many ligamentary cords that unite them, and the muscles that move them.

In the interior, these bones have nothing peculiar, except an abundance of the texture of the cells which forms them almost wholly, and exposes them to frequent caries.

Nature is not however regular in the division of bones into long, flat and short. Here as elsewhere, she disregards our methodical descriptions, and shows us the bones sometimes exhibiting the character of long ones and short, and sometimes uniting the attributes of both these last with the flat ones. The basilary apophysis and the superior part of the occiput, the body and the lateral portions of the sphenoid, when placed in contrast, prove this assertion. A bone sometimes by its external form belongs to

the long ones, but from its internal organization should be classed with the flat, of this the ribs are an example, &c.

IV. *Of the Bony Eminences.*

The bony eminences have generally the name of apophyses; they are called epiphyses when the cartilage of ossification which unites them to the bone is not yet encrusted with calcareous substance.

These eminences have four great divisions; viz. those, 1st, of articulation; 2d, of insertion; 3d, of reflection; 4th, of impression.

1st. The eminences of articulation vary according as the articulation is moveable or immoveable; I shall not consider them here, as I should be obliged to repeat it in the chapter upon articulations.

2d. The eminences of insertion are very numerous in the bones; they only give attachment to the fibrous organs, as the ligaments, the tendons, the aponeuroses, the dura-mater; no organ differing from these is implanted into the bony eminences, or generally into the bones, except by means of them; the muscles are a remarkable example of this.

These eminences are usually much less in women than in men, in children than in adults, in weak animals than in carnivorous ones who live by attacking and destroying their prey. The prominence of the eminences of insertion is always an index of the force and vigour of the motions. They are the more developed in proportion as the muscles are. Examine comparatively the skeleton of a strong, sanguineous man, whose muscles are powerfully delineated through the integuments, and that of a feeble, phlegmatic man, whose rounded forms like those of women, do not appear prominent, and you will see the difference.

The form of these eminences of insertion varies greatly; sometimes the muscles are inserted by many separate

aponeurotic fibres; then they are small, very numerous and form only little asperities imprinted on a greater or less surface; sometimes it is by a single tendon that the muscle takes its origin, then the apophysis is usually very prominent, and occupies a small space. Sometimes a broad aponeurosis gives rise to the fleshy fibres; it is then a bony line, more or less projecting that gives insertion.

The eminences are in general in proportion to the muscles that are attached to them; for example, in three muscles of nearly equal size, one of which is attached by separate fibres, the other by a tendon, and the other by an aponeurosis, we observe that the sum of the asperities of insertion of the first, the separate apophysis of the second, and the prominent line of the third are nearly equal in the quantity of osseous substance that forms them; so that by supposing that the apophysis was divided into asperities, or extended into a line, or that the asperities were united together, or the line concentrated so as to form an apophysis, this quantity of osseous substance would be found to be about the same.

We understand all the advantage of the eminences for the insertion of muscles, which they render distant from the centre of the bone, lessen the parallelism with its axis and consequently favour their motions in an evident manner.

Are these produced by the pulling of the muscles? This opinion borrowed from the laws of the formation of soft and inorganic bodies, does not accord with the known phenomena of vitality, with the existence of eminences where there is no muscular insertion, and which are often more prominent than these, with the disproportion that exists between the elongation of certain apophyses by muscular insertion, that of the styloid, for example, and the force of the muscles that are attached to it, &c.

The eminences for ligamentary insertion have the advantage, by removing a little the ligament from the articulation, of facilitating its motions; this is especially remarkable in the lateral ligaments of the elbow, the knee, &c.

As to the other eminences of insertion, we can hardly consider in a general manner their respective functions.

3d. The eminences of reflection are those under which a tendon passes, in deviating from its primitive course; such is the hook of the pterygoid apophysis, the malleolar extremity of the fibula, &c. Almost all these eminences have a slope or excavation in one direction, connected in the opposite with a ligament, so as to form a ring for the passage of the tendon.

4th. The eminences of impression are those which arise, when the different organs form on the osseous surfaces excavations that separate these eminences, which in fact only appear because the bone at this place remains at its ordinary level. The cerebral and muscular impressions are given as examples of this arrangement. But are these impressions really the effect of the compression of the organs on the bone, or do they arise from the laws of the osseous development, laws which give to the bones forms accommodated to the surrounding organs? I adopt more readily the second than the first of these opinions, which has been thought very probable from the effect of aneurisms upon bones that are contiguous to them, which are worn and gradually destroyed by them. But let us remark that if the muscles, the brain, and the vessels by their pressure, had upon the bones in a natural state, an action analogous to that of aneurism, the state of the parts ought to be the same as in that case. The compact layer ought to be destroyed where these depressions are, and leave in its place an unequal, ragged surface, but the contrary happens, which makes me think, that what is commonly called the impression of organs, is only a natural effect of ossification.

V. *Of the Osseous Cavities.*

The osseous cavities are very numerous; those only which are found on the exterior of the bones will be treated of. They are divided, like the eminences, into articular and non-articular. The first will be examined, with the analogous eminences, in the chapter on articulations. Among the second there are cavities, 1st, of insertion; 2d, of reception; 3d, of slipping; 4th, of impression; 5th, of transmission; 6th, of nutrition.

1st. The cavities of insertion give attachment to the aponeuroses of the muscles, to the ligaments, &c. They have the advantage, 1st, of multiplying the insertions of the fibres, without increasing the size of the bone, since a concave surface is evidently more extensive than a plain surface would be which should occupy the space between its edges; 2d, of allowing the muscular fibres more room, and consequently giving them greater length than if they arose from an eminence, which also gives more extent to the motions. The pterygoid, digastric cavities, &c. present examples of this arrangement.

2d. The cavities of reception are those which serve to receive an organ, lodge and defend it; such are the fossæ of the bones of the cranium, those of the ossa ilii, &c. These cavities sometimes belong to the whole of the bone, the form of which is concave, as we see in the frontal bone, sometimes they are hollowed out upon an insulated part, like the maxillary depression of the inferior jaw; they are always destined for an essential part, for a gland, a viscus, &c.

3d. The cavities of slipping are in general found at the extremity of the long bones. They are grooves, more or less deep, in which the tendons glide to go to the place in which they are inserted. All are covered with a cartilage and terminated by a very strong ligamentary ring. Do the tendons by their friction form these

cavities? This is the common opinion, but it does not appear to me more probable than the theory of muscular, vascular impressions, &c. These cavities ought to be then so much the deeper, in proportion as the muscles are the more exerted; they ought not to exist in subjects paralytic from their infancy; they ought not to exist in the cartilages of ossification in the fœtus, whose limbs have hardly ever moved; but the contrary of all this is constantly observed. Let us describe then all the different configurations of the bones, as a consequence of the laws of ossification, laws in obedience to which the osseous forms, all primitively determined, are made to develop. The size of the extremities of the long bones favours the existence of these different cavities, which cannot on this account injure the osseous solidity.

4th. The cavities of impression correspond with the eminences of the same name. I have spoken of them above.

5th. The cavities of transmission are especially destined for the vessels and the nerves. We find many of them on the head; they have sometimes the form of a groove, sometimes that of a tube and at others that of a slit, according to the thickness or breadth of the bones which these vessels or nerves traverse in order to go from one place to another. The periosteum lines them; they contain more or less cellular texture. The nerves and vessels they transmit are foreign to the bones.

6th. The cavities of nutrition, on the contrary, give passage to vessels which carry to the bones or the medullary organ the substances that repair them. They are of three sorts.

The first form canals that are seen on the long bones exclusively, and go to the medullary cavity. Each bone has but one of these, situated always on its body, directed obliquely between the fibres of the compact texture, running sometimes from below upwards, sometimes from above down into the cavity of the bone, and thus form-

ing a communication from without to within for the vessel of the medullary organ. This foramen serves particularly for the exhalation and nutrition of this organ, and nourishes the bone only secondarily.

The second kind of cavities of nutrition belong especially to the texture of the cells of the bones. Thus they are seen wherever this texture abounds, in the extremities of the long bones, the circumference of the flat ones, and the whole superficies of the short ones. Their diameter is greater than that of the canal which goes to the medullary cavity; it is less than that of the canals of the compact texture. Their number is very considerable; I have counted a hundred and forty upon the tibial extremity of the femur, twenty upon the body of one of the dorsal vertebræ, fifty upon the os calcis, &c. In general this number is always in proportion to the quantity of the texture of the cells that the bone contains. Hence why there are but few on the flat bones of the cranium, why they are more numerous on the flat bones of the pelvis especially where this texture is abundant, as on the ischium, on the iliac portion of the circumference of the ilium, &c. By pouring mercury into the spongy texture, it runs out from all these foramina, and thus proves their communications. They are irregularly scattered wherever they are. They are not met with on the body of the long bones, because the body contains little or none of the texture of the cells.

The third kind of canals of nutrition is only destined to the compact texture. It consists of an infinite number of little pores which the eye can clearly distinguish, and through which small vessels pass, that go to this texture. An evident proof that they do not go to the texture of the cells, is, that in the preceding experiment, the mercury never finds in them a way to escape externally. It is impossible to determine their number; it is prodigious in childhood. As the bones in old age become filled with

calcareous substance, they are obliterated, and the vessels they contain become small ligaments, foreign to osseous nutrition, which continually grows weaker, and is soon annihilated, and allows necrosis to seize upon the bones, if general death does not prevent this partial death of the osseous system.

ARTICLE SECOND.

ORGANIZATION OF THE OSSEOUS SYSTEM.

The peculiar texture of the osseous system forms in it the principal and predominant part, especially as we advance in age. The common organs are in much less proportion.

I. *Texture Peculiar to the Osseous System.*

The texture of the bones, like that of most of the other organs, presents itself under the aspect of fibres whose nature is everywhere the same, but which differently arranged, form two principal modifications; in the one, these fibres being more or less scattered, exhibit many cells; in the other being close to each other, they form a compact substance in which it is difficult to distinguish them. Hence two sub-divisions of the osseous texture, that with cells, and the compact. Authors admit a third one, the reticular; but this is included in the first.

Texture with Cells.

The texture with cells does not exist in the first periods of ossification. The time of its formation is when the phosphate of lime is added to the gelatine of the primitive cartilage, and gives to the organ the bony nature. Then an infinite number of cells is formed in the solid mass of cartilage, because the gelatine, taken up by the absorbents, disappears in the place they occupy.

No more is brought by the exhalants, which begin to carry the phosphate of lime to the fibrous cross-pieces, whose interlacing forms these cells; so that the development of the texture of the cells belongs evidently to the disproportion that takes place in the bones at a certain period of their growth, between the functions of the exhalant and absorbent system, until then in equilibrium. We know not the cause of this disproportion, it appears to be a law of ossification. It is by virtue of this law and by an analogous mechanism, that the os ethmoides, at first solid and full when it is cartilage, is hollowed out at the period of its ossification, into a great number of cells. It is thus that the sphenoidal, frontal sinuses, &c. are formed and enlarged.

The formation of the texture of the cells ceases when all the epiphyses have disappeared. At this period it exhibits to us an infinite number of fibres which appear to arise from the internal surface of the compact texture, go in different directions, cross, unite, separate, bifurcate, in a word, pursue such irregular courses, that it is impossible to follow them. Their size is not less variable; sometimes their delicacy is such, that they can hardly be touched without breaking; at others they are quite large. Often instead of fibres there are layers, of more or less considerable size, from which arise other smaller ones, which appear to ramify, and from which result, when they are near each other, species of canals, which are seen very well by sawing transversely the extremity of a long bone, so as to have a segment of half an inch.

The cells which are made by their separation, are of very unequal form and capacity.

All communicate together; the following experiments prove this. 1st. If we make a hole in the extremity of a long bone, or upon the surface of a short or flat one, and pour in mercury, it passes through all the communications, and comes out of the natural foramina on the sur-

face of the bone, which also open into the cells. 2d. Saw a long bone at one of its extremities, cover its whole surface with something that shuts up its pores, then expose it to the sun; the medullary fluid not being able to escape by the external pores, will come out at the sawed place, after passing successively through all the cells. 3d. By varnishing a dry bone, and opening it only in two opposite points, we can force air, water and every kind of fluid through these communications, from one opening to the other.

We can then consider the interior of every bone as forming a general cavity that is filled by many interlaced fibres. I have not observed a sensible difference in the direction of these fibres in the three kinds of bones.

Compact Texture.

The fibres that form the compact texture are not the same as those of the preceding. These fibres, being in juxta-position, not leaving any space between them, giving by their approximation a remarkable density to the texture they form, have a longitudinal direction in the long bones, are in the form of rays in the flat ones, and cross each other in all directions in the short ones. This triple arrangement of the fibres of the compact texture appears to be wholly owing to the manner of ossification. In fact, when we examine its progress in the primitive cartilages, we see these organs encrusted with the phosphate of lime, in the same direction which these fibres afterwards take. Thus these fibres are very evident in the first age, on the bones of the cranium in particular. When the phosphate of lime, successively deposited on the cartilaginous parenchyma, predominates there, then the whole is confounded in the compact texture in one homogeneous mass. But still there are different circumstances that indicate the primitive direction of the fibres: 1st. When by an acid we remove from bones their calcare-

ous part, then the cartilaginous portion keeps as a kind of mould, the form of the substances that filled it, and exhibits fibres whose direction is the same as that pointed out for the three species of bones. If we wish to separate the cartilaginous layers, it is in this direction that it is most easily done. 2d. The fissures that come in bones long exposed to the air follow in general the natural direction of the fibres. 3d. Calcined bones exhibit nearly the same phenomenon.

The direction of the fibres of the compact texture is changed entirely in the apophyses, in which it does not follow that of the principal bone. In those, which by their form, partake of the character of the long bones, as in the styloid, these fibres are longitudinal ; they go in all directions in those, which like the mastoid, the different species of condyles, &c. resemble in their shape the short bones.

The assemblage of the fibres forms, according to anatomists, layers which they have considered as in juxtaposition, and held together by little pins according to some, and by the interlacing of fibres according to others. These osseous layers do not appear to me to exist in nature. All the fibres of the compact texture adhere to each other, cross and form a whole that we cannot conceive of in this manner, and which besides does not accord with the irregularity of the distribution of the vessels. Art separates here fibres layer by layer, as it is done in a muscle, in a ligament, &c. ; but these layers are wholly factitious ; to exhibit the bones as formed by an union of these layers is to give a very inaccurate idea of their structure. It is still more inaccurate to consider these layers as attached to each other by osseous pins, by attraction, or by a glutinous matter which serves as a glue. All these ideas, contrary to anatomical examination, suggested by a false application of the laws of the adhesion of inorganic bodies to the adhesion of organized fibres,

now belong only to the history of physiological errors. There is a circumstance, it is said, that very evidently proves the lamellated structure of the bones, it is their exfoliation. It is true that often very distinct layers are separated from the living bone, but these layers are only the product of exfoliation itself. Then in fact the bone dies on the surface; the superficial vessels receive no more blood; this fluid is stopped under the portion deprived of life, the exhalation of the phosphate of lime ceases there, every kind of sanguineous, exhalant and absorbent vessel is destroyed; a slow inflammation, with suppuration, comes on, and fixes the line of demarcation; and as this line is often at the same place, all which is above it becomes an inorganic layer which gradually falls off, and preserves its osseous solidity, because the dead absorbents were not able to remove the phosphate of lime. Besides, nothing is more common than to see exfoliation take place not by layers, and the bone afterwards exhibit an unequal surface, the effect of the inequality of the thickness of the exfoliated portions. Finally, exfoliation often takes place in a direction opposite to that which the layers are thought to have; this is what we see in the separation of the extremity of the long bones, that have been exposed to the air or too much irritated after amputation, in the shedding of the horns of animals, &c. Let us consider the compact texture as an assemblage of condensed fibres, not separated by layers, which we can only consider as imaginary.

The fibres of the compact texture differ in their organic arrangement, from the muscular fibres in this, that frequent elongations unite them to each other, whereas the muscular have only the cellular organ, the vessels and the nerves as the means of union. Such is the intimate juxta-position of the fibres of the compact texture, that they leave between them only pores hardly sensible to the naked eye, but which become so however with a

glass, and which the medullary juice and vessels fill. In the rickets this density of texture disappears, and we observe in the middle part of the long bones and under the layer of periosteum more thick than common, an osseous texture, easily bent in all directions, forming an infinity of cells and taking the place of the compact texture that ought to be there. It appears that this change of compact texture into that of cells is made less by the absorption of a part of the phosphate of lime, than by the extension of the osseous fibres which separate from each other, and leave between them spaces that did not before exist; this gives to the bodies of long rickety bones a very considerable thickness. I have many times made this remark.

Arrangement of the two Osseous Textures in the three kinds of Bones.

The osseous textures, considered in the different kinds of bones, are differently arranged. In general the compact forms the exterior, the covering of the bone, and that of the cells occupies the interior. The ossa spongiosa form an exception to this rule, the modifications of which we shall now examine.

1st. In the long bones, the compact texture has a very remarkable thickness in the centre, where it serves the triple purpose, first of protecting the medullary organ, of which it is the covering, then of giving solidity to the bone in this place, which more than the extremities, is exposed to great efforts in locomotion, falls, concussion, &c. and where the bone, traversed only by some very weak fibres of the cells, cannot borrow its resistance but from its external parietes; finally, of thus diminishing without danger the size of the bone in the middle part of the limb, the form of which, becomes by this means much more regular. So that as we go from the centre, we see in a long bone, sawed longitudinally, the compact texture

diminish in thickness, and form at last at the extremities only a delicate layer analogous to that which covers the short bones. Thus the power of resistance of the long bones, at their extremity, is less in their compact shell, than in the great quantity of the texture of the cells deposited under it; it is this especially that prevents fractures; hence we see how the proportion of the compact texture and that of the cells being inverse in the two parts of the bone, the manner of their resistance is also inverse.

The texture of the cells differs a little when examined in the medullary canal and in the extremities. In the canal there are extremely delicate filaments, continued from larger fibres which fill above and below the extremities of the bone, and the compact portion which forms the osseous cylinder. Few and scattered at random in the middle of the canal, these filaments approximate each other, and form a kind of net-work, as they go from it; hence the name of reticular substance by which it is designated. But it is not a distinct texture, it is only a modification of that of the cells; a modification, which is especially characterized, 1st, by the delicacy of the fibres; 2d, by the uniform absence of those fine and short layers which frequently belong to this texture in other parts. Besides, the manifest use of this portion of the texture of the cells, too weak to contribute to the resistance of the bone, is evidently to serve as a support to the medullary system, and insertion for its membrane. At the extremities of the long bones, the fibres of the texture of the cells increase a little, approximate each other, are scattered in layers, and give to the bone by their union and number, a remarkable thickness and resistance, without however increasing the weight, which very much favours locomotion, considering that this weight placed at the extremity of the lever would have been very painful to raise.

2d. In the flat bones, the compact texture forms two external layers, the thickness of which is between that of the middle of the long bones, and that of the extremity of the same bones, or that of the short ones. Between these two layers is found the texture of the cells, similar in general to that of the extremity of the long bones, a little more lamellated however, thicker usually at the circumference, often almost wanting in the middle of the bone, where its two compact layers in juxta-position allow a light to be seen through it, when placed behind. In general wherever the broad bones are so thin, from the want of the texture of the cells, there are very strong muscles, which by their thick layers give solidity to the bone. We see examples of this in the iliac, sub-scapular, inferior-occipital fossæ, &c.

3d. In the short bones, the texture of the cells always predominates; the bone is almost wholly formed of it, a delicate layer of compact texture forms only its covering, and in this respect, the organization of these bones is the same as that of the long bones at their extremities; thus the resistance of the bone depends on the whole of its mass, and no part makes a greater resistance than another against fractures. We see, from all that has thus far been said, the successive manner of the solidity of the different bones. In the middle of the long bones, there is hardly any thing but compact texture to which it is owing; in the flat bones it is as much to this texture as to that of the cells; in the extremities of the long bones and in the short ones it is almost to this last only that its solidity is owing.

4th. In the osseous eminences, the compact texture is more abundant than elsewhere, especially in those of insertion, as in the prominent lines of the long bones, which are all formed of it, in the asperities of the osseous surfaces, in their angles. If the eminence is considerable, there enters into it also more or less of the texture

of the cells as we see in the spinous and transverse processes of the vertebræ, in the coracoid, mastoid, &c. processes. The eminences of the moveable articulations have in general less of the compact texture, solidity is given to the bone by the articular cartilage. Those of the immoveable articulations, on the contrary, in general smaller, as the sutures of the bones of the cranium, for example, are in proportion more compact than cellular.

5th. In the osseous cavities, all those which serve for moveable articulations, are only furnished with a very delicate compact layer; it is thicker when the articulations are immoveable. In general all the foramina, cavities and canals that transmit from one region to another vessels, nerves or other organs are everywhere lined with a compact layer that defends them from the impression of these parts. The foramina at the base of the cranium, the dental canals, the vidian foramina, &c. are examples of this arrangement.

Of the Composition of the Osseous Texture.

Whatever may be the modifications under which it is exhibited, the osseous texture has everywhere the same nature; the same elements form it; now these substances are especially a saline calcareous substance and a gelatinous one.

The existence of the saline substance in the bones is proved in different ways. 1st. Combustion, by destroying the gelatinous portion, leaves a friable, brittle body, of a form analogous to that of the bone and which is nothing but this saline substance, which resembles, if we may so say, a moulded body that keeps the form of the mould after it has been taken away. If the combustion is pushed very far, and a red heat produced on the calcined bones, they undergo a semi-fusion, which makes them resemble the state of porcelain; they have then a very compact, fine, semi-vitreous grain, a semi-transparency,

and an appearance like that of the vitrified earths. 2d. The long continued exposure of the bones to the air produces an effect very similar to that of the first degree of combustion, though however the gelatine is rarely so thoroughly removed, and the saline portion so perfectly exposed as by the action of fire. Besides, it requires a very long time to produce this effect, especially upon the thick bones; the thin ones are more easily altered; I have often made this observation. After ten years exposure to the air and rain, I have observed that clavicles taken from the cemetery of Clamart, exhibited upon the action of the acids, a cartilaginous parenchyma almost equal to that of a bone that had been some time dried. But this parenchyma finally disappears, and the bone falls to powder, when it is no longer supported by it, and the particles of the remaining calcareous substance have been disunited by time. 3d. In the last stages of all cancerous diseases, the bones have a friability which is only owing to the greater proportion of this last substance, a proportion arising itself from the small quantity of gelatine that is then exhaled in the bones. 4th. When a bone has been for some time exposed to the action of an acid, the nitric for example, a portion of its substance is taken from it by this acid, which is evidently a calcareous salt, as can be seen by mixing it with a solution of an alkali, which uniting immediately to the acid, exposes this salt, by making it precipitate. 5th. Papins digester, by dissolving by the action of water reduced to vapour the gelatinous portion, shows also this saline calcareous part.

Scheele has found that this portion is a neutral salt with an earthy base, the phosphate of lime. Frequently the phosphorus in fresh bones give them a luminous appearance, that can be seen very far in the night. It is sometimes the whole of the bone, sometimes some parts only that become luminous. I have always observed in the illuminated places an oily exudation, either that

comes from the medullary juice, or is furnished by the fat of the neighbouring soft parts of the bone.

Different facts as evident as the preceding, prove in a manner not less certain, the existence of a gelatinous substance in the bones. 1st. When in the solution of the bones in the acids, the phosphate of lime has left them, there remains a cartilaginous, flexible, elastic body, yellowish when nitric acid is employed, of the same form as the bone. Now we know that the gelatine especially nourishes the cartilages. 2d. If besides we subject this cartilaginous residue to ebullition, we extract a very great quantity of gelatine which is dissolved in the water and can be afterwards precipitated by tannin. This substance can even be removed from the bones without the previous extraction of the phosphate of lime ; it is thus that with bones stripped of every surrounding organ, and reduced to very small fragments or even to powder by the action of a rasp, very nourishing broths and jellies are made. It is not without reason that in the preparation of boiled meat, the bone is left attached to the meat ; besides the white organs that surround it, and the medullary oil that it contains, it furnishes to the broth a substance that is peculiar to it. 3d. The combustion of the bones, and especially of their cartilaginous residue, gives an odour exactly similar to that of the combustion of the different animal glues, which, as we know, the gelatine especially forms. 4th. In the different affections in which the bones become soft, the earthy substance is diminished more or less sensibly, and the gelatinous remains more abundant in proportion than common.

These two substances, the gelatinous and saline, which enter essentially into the composition of the bones, imprint upon them very different characters. The phosphate of lime, almost foreign to vitality, is only destined to give to the bones the solidity and resistance that characterize them. The gelatinous substance, on the con-

trary, has especially the animal character; thus the vital activity is in the inverse ratio of one and the direct ratio of the other, as we shall see. Deprived of gelatine, the bones are not capable of being digested, they offer nothing for the gastric juices to act upon, they cannot extract nutritive matter from them, because they act upon them nearly as water does, which dissolves the gelatinous substance and extracts it from the saline portion. Different animals that swallow fresh bones for nourishment, would die from eating a calcined one; thus the more the bones contain of this substance, the more nourishing they are; those of young animals are on this account more proper to make gelatinous broths, more suitable to be digested raw by the stomachs of certain species, &c. If we expose a bone to the action of an acid, so as to have only its cartilaginous parenchyma left, and afterwards soften this parenchyma in boiling water, it becomes an aliment that can be eaten.

Besides phosphate of lime and gelatine, the bones contain also some saline principles, as the sulphate and carbonate of soda, &c. But this proportion is too small to be noticed. Upon this point, I refer to chemical books, especially to the great work of Fourcroy.

II. *Common Parts which enter into the organization of the Osseous System.*

The ancients ranked the bones among the white parts, among the tendons, the cartilages, &c. It is sufficient however to examine the interior of them to see, by the redness that distinguishes them, that much blood enters them. This blood penetrates in three orders of vessels; one belonging to the medullary cavity of the long bones, another to the texture of the cells, and the other to the compact texture. These two last orders distributed in the osseous texture, appear to be especially destined to deposit the phosphate of lime; for in the cartilages of

ossification, the white vessels alone carry the gelatine; in other cartilages it is the same; so that I think that this kind of vessels is also destined in the bones which are perfectly formed to nourish their cartilaginous parenchyma, whilst the red vessels belong more to their calcareous portion.

Each medullary cavity has only one vessel, and only one foramen of nutrition. This vessel has a diameter proportioned to that of the bone which it penetrates, and in which it is divided immediately into two branches, without permitting any ramification on the compact texture. These go in an opposite direction to the two extremities of the bone, ramify ad infinitum in the medullary organ, and their last branches are lost in the commencement of the texture of the cells, where they anastomose with the vessels of this texture; that which occupies the medullary cavity under the name of reticular, and the internal surface of the compact texture, receive also some branches. A vein everywhere accompanies the artery, and follows the different distributions of it.

The vessels of the second order belong to the texture of the cells of the long, flat and short bones; they are equal in number to the foramina of this texture, and ramify on its cells; they communicate with those of the marrow and of the compact texture. At death, the small arteries in general remain full of red blood, which indicates their course which their minuteness would conceal, and which injections can rarely demonstrate with accuracy. The accompanying veins of these arteries can hardly be seen.

The blood-vessels of the third order are only the last ramifications of the arteries surrounding the bones, ramifications which enter in great number the compact texture, and stop there. The existence of these vessels may be proved in different ways. 1st. By detaching the dura mater from the internal surface of the cranium, many

small sanguineous drops prove their rupture. 2d. By raising on a subject of a middle age the periosteum, we make the same observation. I have remarked that these experiments succeed especially on those that have been drowned, or on animals destroyed by asphyxia, on account of the great quantity of blood their vessels contain. 3d. If we fracture a long bone in the middle, the compact portion, which forms the medullary canal, exhibits small reddish striæ, which are nothing but these small vessels still full of blood, and of which we thus discover a greater or less number, according to the manner in which the blood was arrested in the capillary system at the instant of death. 4th. The saw-dust of the compact texture in living animals is red, though less evidently so than that of the texture of the cells; a proof that these vessels have been divided.

The vessels of the bones are very numerous in childhood; they diminish in the adult, and become scarce in old age. The facility of the formation of callus follows the same proportion in the different ages of life. Often in affections of the osseous parenchyma they have a remarkable development, which much exceeds their natural diameter. Osteo-sarcoma, spina-ventosa, &c. exhibit this, which is much oftener observed in cancerous tumours than any other.

These vessels communicate with each other by numerous anastomoses; this is what we see especially in the long bones, between those of the medullary organ and those of the texture of the cells. By these communications, they mutually assist each other's functions. I have seen the nourishing foramen of the tibia completely obliterated in a body that I injected. A sort of cartilage filled this foramen; the artery formed a real ligament. Yet its bifurcation in the medullary canal was found very well injected, and besides no alteration appeared in the nutrition of the medullary organ, which had probably received

as much blood as usual. I found nothing in the neighbourhood of the foramen, which showed the cause of this obliteration, which an exostosis, an affection of the periosteum, or an inflammation can very easily produce.

On the other hand we know that very considerable osseous layers are often taken from the extremity of the long bones by caries, which consequently destroys all the vessels corresponding to these layers, and yet the bone beneath lives, principally by the blood that it receives by the extremities of the artery of the medullary organ. This is nearly what happens to the long bones in the first age, in which the cartilaginous extremities have not vessels of the second order, and in which consequently almost all the blood comes from this same artery of the medullary organ; thus it is much larger in proportion, and the foramen which receives it much more considerable.

Nothing is yet known upon the systems of absorbent and exhalant vessels of the bones, and we can reason upon this point only from analogy. Besides the nutritive process evidently supposes them there.

As to their cellular texture, it appears to be almost nothing; we can even say that in whatever place we break the compact fibres or those of the cells, its filaments are not distinct; but it is their dense and compact texture that conceals them from us. In fact, 1st, when this texture is softened, and the bone has become flesh, as it is called, the cellular texture is very apparent there. 2d. The fleshy granulations, rising on places that have been fractured or laid bare, are only the extension of the cellular texture which has too much calcareous substance to allow it to be seen in the natural state. 3d. After having removed from a fresh bone all this substance by an acid, I have sometimes observed cellular filaments by separating the cartilaginous fibres which form the parenchyma that is left. 4th. When we boil this cartilaginous parenchyma in order to extract the gelatine from it, there

remains portions of membranes which are evidently cellular.

We cannot trace the nerves in the bones, the filaments that enter them are so fine; I do not know that anatomy has any positive data upon this point.

ARTICLE THIRD.

PROPERTIES OF THE OSSEOUS SYSTEM.

I. *Physical Properties.*

The bones have very strongly marked physical properties. Solidity and hardness are their peculiar portion; they derive these properties from the phosphate of lime which penetrates them, thus they are constantly increasing with age, because this substance becomes more and more predominant. Elasticity is another physical property of the bones, which is found combined with the two preceding, but which is in an inverse order; as it is in the gelatinous substance, in the cartilaginous portion of the bone that it resides, it is, like this portion, greater in childhood. In old age, the bones lose entirely their suppleness and elasticity; they break more easily. Elasticity is more evident in the long and small bones, than in those which are larger; the fibula bends and evidently goes back again, this the tibia could not do without difficulty. It is not that the one is more elastic than the other, but it is that its conformation is more favourable to the development of this property.

II. *Properties of Texture.*

Although the hardness and solidity of the osseous texture seem to be opposed to every kind of extension and contraction, yet these two phenomena and the

properties of texture from which they arise, are often very evident in it.

The extensibility of the osseous fibres is proved by the observation of many diseases, for example, the spina ventosa, the swelling of the maxillary sinus when it contains a polypus, by the enlargement of the bones of the cranium in hydrocephalus, &c. I would remark on the subject of these different distensions, that often by the influence of analogous causes, the bones which yield and are distended in the above cases, are broken, worn and destroyed in others. A polypus of the nose breaks through the naso-palatine partition, without having first distended it; aneurism of the aorta does not bend the sternum or the vertebræ, but it breaks through and destroys these bones. Whence arises this difference from causes nearly the same? This is not easily determined. The contractility of texture is very evident in the bones, when the cause which distended the fibres is removed. We see the alveoli contract, and become effaced, when a tooth has been drawn from them. The diminution of the thickness of the jaw after cutting the teeth arises only from the contraction of its fibres, which are no longer distended as much, because the root is not so broad as the crown, which had till then been wholly in the bone. The maxillary sinus contracts when a fungus is removed from it, or pus is discharged from the carious bone, &c. If death was not too soon the consequence of the puncture of the head of hydrocephalic patients, I am persuaded that we should see the bones gradually contract, and restore the cavity of the cranium to its natural dimensions. When we remove the dead piece from a long bone in necrosis, the new bone, formed on the exterior by means of the periosteum contracts in an evident manner. In paralysis of the optic nerve, its foramen becomes narrower. The orbit contracts when a cancerous eye has been extirpated. I have dissected the

carotid canal in a dog whose carotid I had tied; there was no contraction because the blood coming by anastomoses dilated the artery to the usual size.

This contraction of the bones, by means of the contractility of texture, is not so sudden as that of the muscles, the skin, &c. when they are no longer distended by a tumour, an aqueous collection, &c. This arises from the difference of the organic texture, from the rigidity of osseous fibres owing to the calcareous substance they contain, &c. Thus the organic sensibility is less evident in them.

III. *Vital Properties.*

The bones have hardly any animal properties in a natural state. Their sensibility is nothing; the saw, the mallet, and the chissel act upon their texture almost with impunity; an obscure feeling is the only result of the action of these instruments; fire even can act upon them without making the animal suffer much. But in a morbid state, the sensibility is developed to the greatest extent; we know the horrible pains that attend spina-ventosa, and those not less severe that caries produces in certain cases. If a bone is inflamed, as for example the sawed extremity of a stump after amputation, this bone which in a natural state had borne, without transmitting any painful impression, the action of the saw, becomes as it were a new sensitive organ, to which the least touch is painful. The animal contractility is nothing in the osseous system.

The organic properties give life to this system as to all the others. The sensibility of this kind certainly exists in it; the fluids that penetrate it are felt, and by virtue of this feeling, those are appropriated to it which are proper for its nutrition. But is there in the osseous system a reaction upon these fluids? are there those insensible oscillations which compose insensible organic contractility? Its hardness seems to prevent them. But

yet the circulation is carried on there; it performs a constant work, an habitual composition and decomposition, which can hardly be conceived of without reaction on the part of the osseous system. Besides this reaction is more slow, more difficult on account of its structure; and hence without doubt the slowness, of which we shall speak, in the vital phenomena of the osseous system. Sensible organic contractility is foreign to it.

Character of the Vital Properties.

The peculiar life of the bones is composed then of only two vital properties, organic sensibility and insensible organic contractility. From these two properties are derived all the vital phenomena that these organs exhibit, inflammations, formation of tumours, cicatrization of solutions of continuity, &c. This peculiar life is remarkable in general, as I have just observed, when compared with the peculiar lives of the other organs, by its slowness, by the tardy concatenation of its phenomena. All things being equal as to ages, and the different proportions of the earthy and cartilaginous substances, inflammation is more slow there than in the other parts. Callus is remarkable among the other cicatrices by the length of its formation; compare an exostosis in its origin, its progress and its development, with a tumour of the soft parts, a phlegmon for example, and you will see the difference. Who does not know, that whilst suppuration often requires only a few days in the other organs, it is whole months in forming in the middle of the bones? Observe the difference that there is between a gangrene of the soft parts, in which death takes place in a short time, with caries and necrosis of the bones, in which a long period elapses between disease and death of the part. In general we can say, when inflammation exists in a bone, that it is chronic.

Sympathies.

This character of the vital properties imprints an analogous one upon the sympathetic relations of the osseous system with the other systems. At first the animal contractility and the sensible organic contractility cannot be put in action in these relations, as they do not exist in the bones. The animal sensibility being developed in them with difficulty and slowly by the diseases that essentially affect them, the sympathies can be brought into action in them only in an obscure manner. These symphathies then should act essentially upon the organic sensibility and upon the insensible organic contractility, and as these two properties are developed slowly, the different sympathies should not be connected with the acute affections of the other organs, and this is what is clearly proved by observation. In fact observe that whilst many other systems respond with great quickness to the acute diseases of an organ, this, as well as the cartilaginous, fibro-cartilaginous systems, &c. remain then almost always in inaction. Let the stomach, the lungs, the brain, &c. be the seat of a severe acute disease, you see immediately many sympathetic phenomena arise in the nervous, vascular, muscular, glandular, cutaneous, mucous systems, &c. &c.; all seem to feel the trouble of the affected organ; each, according to the vital forces that predominate there, exhibit different phenomena, which are only aberrations, irregular developments of these forces; in the animal muscular system, it is the animal contractility which is especially raised; hence spasms and convulsions; in the glandular, the serous, the cutaneous, the mucous, &c. the insensible organic contractility and the organic sensibility principally experience alterations; hence the different sympathetic derangements of the secretions, of the sweat, of the exhalations; in the nervous, it is the animal sensibility which is especially brought sympathetically

into action; hence the wandering or fixed pains in different parts; in the organic muscular, it is the organic contractility which is raised; hence the irregular motions of the heart, the stomach and the intestines. In all the acute diseases of an organ there are always two orders of symptoms, the one relative to the affected organ, as are the cough, the pain in the side, the spitting of blood, the difficulty of respiration, &c. in peripneumonia; the others purely sympathetic and arising from the relations which connect the vitality of this organ with that of all the others; now these last are often much more numerous than the others.

Observe the bones in the midst of all that general sympathetic derangement of the systems in which life is very active; they undergo no alteration; their life, more slow than that of the other systems, is not connected with these phenomena which have an acute character; neither is that of the cartilages, the fibro-cartilages, the hair, the aponeuroses, &c. All these systems, remarkable by the same character of vitality, do not respond to the acute affections of the other systems; they are not sympathetically affected, during these affections, at least in an evident manner. Observe all the acute fevers; their numerous phenomena have an effect only upon those systems in which life is very active; those in which it is distinguished by an opposite character, have uniformly no connexion with these phenomena; they are, if we may so say, calm and tranquil in the midst of the tempest which agitates the others. Let us take for example the different eruptions that appear in fevers; it is upon the skin, the mucous surfaces, &c. that they come; they arise during the fever and they disappear with it; now the bones, the cartilages, &c. could not, from their kind of life, admit of this sudden origin and disappearance.

It is then in the slow and chronic affections that we must seek for examples of sympathies of the osseous.

cartilaginous systems, &c. In the first stages of the venereal disease, in which it is marked only by acute symptoms, or in which at least its progress is not very slow, as when it appears in buboes, in inflammations of the urethra, &c. it has no influence upon the osseous system; it is only when it is of long standing, when it has, as it were, degenerated, and become chronic, that it makes the bones the seat of pains, of different tumours, &c. Besides, I do not know, that we have yet thoroughly analyzed the osseous sympathies. I have shown only their general character. We shall understand them better, when we have given more attention to the relation that there is in diseases between the affection of each organ, and its kind of vitality.

Seat of the Vital Properties.

The bones penetrated by saline substances which tend continually to obey the laws of affinity and attraction, and to make these laws predominate over those of sensibility and organic mobility, seem to hold a middle place in living bodies, between these bodies and inanimate ones. There is truly but one part of their osseous texture which partakes of the vital phenomena, viz. their cartilaginous substance; the other part or calcareous substance is foreign to them; thus the proportion of each of these substances determines in the bones their degree of life. In infancy, in which the first predominates, in the early stages of the formation of callus, in which it is exclusively found, in the softening of the bones in which it remains almost alone, all the vital phenomena become more evident and more powerful. On the contrary, as age accumulates in the bones the saline substance, as in certain animals this accumulation takes place by the natural laws of ossification in some external portions of the system with calcareous base, as in the horns of stags, the shells of crustaceous animals, &c. so life is, if we may so say, succes-

sively destroyed in the bones ; it becomes nothing, when this calcareous portion predominates considerably ; this is what happens in the necrosis which produces the fall of the horns, the casting of the shells of crustaceous animals, &c.

Besides, that which shows the vital energy in an organ, is the rapidity with which inflammation goes through its periods in it, and the frequency of this affection, &c. Now in the bones inflammation is so much the more rapid, in proportion to the greater quantity of cartilaginous texture they contain ; observe the periods of the formation of the callus in the different ages, periods which are determined by the duration of the inflammation necesssary for its formation, you will see that in infancy they are short, that they are much longer in old age, and that often even consolidation does not take place, whilst it is effected with facility in all the soft parts. The general weakness no doubt of all the vital forces which takes place from the effect of age is one cause of this slowness and this rapidity in the formation of the callus at the two extreme periods of life ; but the different proportions of gelatinous and calcareous substances contribute much to it also ; for when we compare other cicatrices with this, the cutaneous, for example, we see that age establishes in them an infinitely less sensible difference as it respects the slowness and rapidity of this reunion, than in the osseous system. The bones have not sufficient life to inflame and unite, like the skin, the muscles also exhibit this phenomenon in a very evident manner. I have seen an old man, the neck of whose fractured thigh-bone remained a long time without reunion, and in whom a wound of the face was healed very speedily by the first intention.

Finally, there is a simple experiment that I have often made, and which proves as well as the preceding facts, that the cartilage is truly the animal part of the bone. We know that one of the great attributes of animal sub-

stances, is to contract and exhibit the horny hardening when burnt; now when the bone is penetrated with its earthy salt, it has not this kind of combustion; deprived of this salt by an acid, the cartilaginous parenchyma which remains burns in this manner. The flat bones in infancy in which this parenchyma predominates, exhibits also this phenomenon in burning; it forces the calcareous portion, which is in small quantity to obey the impulse that it gives it, and turns it in various directions; but in the adult in whom the calcareous portion is the largest, the bone remains unmoved while the fire penetrates it, and its whole cartilage is taken away, without its fibres being able to obey their tendency to the horny hardening which combustion imprints upon them.

ARTICLE FOURTH.

OF THE ARTICULATIONS OF THE OSSEOUS SYSTEM.

All the bones are united together, and thus form the skeleton. The manner of their union varies, but whatever it may be, it is known under the general name of articulation.

I. *Division of the Articulations.*

All the articulations can be referred to two general classes. Mobility is the character of the first, immobility that of the second.

One belongs to all the bones which serve for locomotion, to some of those destined to internal functions, as the ribs, the lower jaw, &c. The other is especially met with in the bones, the union of which forms the cavities designed to defend the organs; this we see in the head, the pelvis, &c.

Moveable Articulations. Observations upon their Motions.

I divide moveable articulations into four kinds, the characters of which are borrowed from the different motions they execute. To understand this division, it is necessary previously to know the motions of the articulations in general. These motions can be included under four species, which are, 1st, opposition ; 2d, circumduction ; 3d, rotation ; 4th, sliding.

1st. The motion of opposition is that which is made in two opposite directions, for example, from flexion to extension, from adduction to abduction, and vice versa. This motion is extensive or limited ; extensive when it is made in all directions, first in the four named above, then in all the intermediate ones ; limited, when it only takes place from flexion to extension, from adduction to abduction, &c. The thigh in its articulation with the pelvis enjoys an extensive motion of opposition. The tibia in its articulation with the femur has a limited motion of opposition.

2d. Circumduction is the motion in which the bone describes a kind of cone, the summit of which is in its superior articulation, and the base in the inferior ; so that it is found successively in flexion, adduction, extension and abduction, or in abduction, extension, adduction and flexion, according to the motion by which it begins, and that moreover it goes through all the intermediate directions. Hence we see that circumduction is a motion composed of all those of opposition, and in which the bone, instead of moving from one direction to an opposite one, as in the preceding case, moves from one direction to another nearest to it, describing thus by its extremity a circle which is the base of a cone of which I have spoken, and which is so much the greater as the bone is so much the longer. We easily understand that among the bones,

those only whose motion of opposition is loose, enjoy that of circumduction.

3d. Rotation is wholly different from the preceding motion. In this there was locomotion, a moving of the bone from one place to another; here it remains always in the same place; it only turns upon its axis. The humerus and the femur enjoy this motion which is simple.

4th. Sliding belongs to all the articulations. It is an obscure motion, by which two surfaces go in an opposite direction, by sliding as it were upon each other. In all the other motions, this is met with; but it often exists without them.

It is easy to understand, from these views upon the articular motions, the division into genera of the class of moveable articulations. In fact, there are articulations in which all the motions are united; in others, there is no rotation; in many rotation and circumduction are wanting, and opposition exists only in one direction; some have only rotation. Finally, there are those in which rotation, circumduction and opposition are nothing, and sliding alone remains.

Hence we see that nature moves here as elsewhere by gradation, that from the most moveable articulations to those that are the least so, there are different degrees of decrease, that she descends gradually to the immoveable articulations, that she is finally reduced to the motion of sliding alone, like that which exists at the carpus, the tarsus, &c. There is even an intermediate one between sliding and immobility; it is the articulation of the symphysis pubis; which can be considered with that of the humerus as forming the two extremes of the series of moveable articulations.

All the articulations of which I have spoken are with contiguous surfaces; this is the general character of those which are moveable. There is however an exception to this rule; it is the articulation of the body of the verte-

bræ, in which there is continuity and mobility. The symphysis pubis is also in part continuous in its surfaces, and yet has sometimes obscure motions. Hence arises a division of the moveable articulations, into those with continuous surfaces, and into those with contiguous ones.

Immoveable Articulations.

The immoveable articulations are sometimes with surfaces inserted into each other, as the bones of the cranium, in which many projections and depressions reciprocally receive each other; sometimes with surfaces in juxta-position, as in the articulation of the temporal with the parietal, the two superior maxillary bones with each other; sometimes with implanted surfaces, as in the teeth.

All the different divisions that I have mentioned will be easily understood by the following table; it is not the same as that which I have given in my treatise on the membranes; I think it presents a classification a little more useful in this, that it offers for a characteristic two things essential to be known in all kinds of moveable articulations, viz. 1st, the relation of the articular surfaces which characterizes the orders; 2d, the number of motions of each which distinguishes the genera. There are no orders in the immoveable articulations because, except the relation of surfaces, the articulations have not differences sufficient to occasion them to be subdivided.

Table of the Articulations.

	CLASSES.	ORDERS.	GENERA.
ARTICULATIONS.	1st. Moveable.	1st. With Contiguous Surfaces.	1st. Extensive Opposition, Circumduction and Rotation.
			2d. Extensive Opposition and Circumduction.
			3d. Limited Opposition.
			4th. Rotation.
			5th. Sliding.
		2d. With Continuous Surfaces.	
	2d. Immoveable.	1st. With Surfaces in juxtaposition.	
		2d. With Surfaces inserted into each other.	
		3d. With Surfaces implanted.	

After having thus divided the articulations, let us offer upon each class some general observations. But let us first remark that the preceding table, considered in respect to the moveable articulations with contiguous surfaces, indicates perfectly the disposition of these articulations as to luxations, which are so much the more frequent as the motions are more extensive. The first genus is the most exposed to it, the last the least so; and the others are more or less so according to their distance from the first.

II. *Observations upon the Moveable Articulations.*

The class of moveable articulations is the most important to be considered, because their mechanism is the most complicated of the two orders composing this class, as we have seen. The latter, or that of the articulations with continuous surfaces, will not be considered in our general observations, as it embraces only one species of motion, that of the vertebrae, this motion will be noticed in the examination of the spine. The order of the moveable articulations with contiguous surfaces, comprises, as

we have said, five genera characterized by their respective motions.

First Genus.

Extensive opposition, circumduction and rotation characterize this genus. The first by the extent and number of its motions. The articulations of the humerus with the scapula and the femur with the ilium are examples of it; they even exclusively compose it.

We see why it is at the superior part of the limbs that nature has placed this genus. A double advantage results from this situation. On the one hand, very far from the part of the limb immediately exposed to the action of external bodies, it more easily escapes luxations to which its want of solidity renders it liable. On the other hand, it can by this situation give to the limb the motions of a whole which compensate for those of the inferior articulations, the solidity of which prevents the power of motion in all directions. For example, the two articulations of which I have just spoken, are not only the articulations of the bones that form them, of the humerus and the femur, but also the articulations of the whole limb, which they direct in different directions; thus the anchylosis of these articulations renders the limb completely useless, whilst that of the inferior articulations only destroys partial motions.

The kind of motion of this genus of articulation requires a rounded form in the articular surfaces, whether they be concave that receive and convex that are received. This form is in fact the only one that can accomodate itself to extensive opposition, rotation and circumduction united; this is the form of the superior parts of the humerus with the scapula, and the femur with the os innominatum. The bone which moves has a convex surface, that which serves for support a concave one. There are in animals examples of an opposite arrangement:

that is to say that a concavity is moved in all directions upon a convexity; but this is not found in man.

Though the two limbs have between them the greatest analogy in their motions, yet there are some differences relative especially to their respective uses, which in the one are for seizing and repelling bodies, in the other destined to locomotion. The principal of these differences is, that rotation and circumduction are found in them in an exactly inverse ratio. The mechanical reason and advantages of this arrangement are easily understood.

In the femur the length of the neck which is the lever of rotation, gives much extent to this motion, which supplies the pronation and supination that are wanting in the leg; so that every rotation of the foot is a motion of the whole of the limb. In the humerus on the contrary, the neck being very short and bringing the axis of the bone near the centre of the motion, limits rotation, which is less necessary on account of that of the fore-arm; the motion of the hand without or within is never communicated but by a part of the limb.

As to circumduction, the length of the neck of the thigh is an obstacle to it. In fact, let us remark that this motion is much the more easy, when it is performed by a rectilinear lever, because then the axis of the motion is the axis of the lever; that on the contrary, if the lever is angular, the motion becomes so much the more difficult because the axis of the motion is not that of the lever; and in general we can say, that the difficulty of the motion is in the direct ratio of the distance of the two axes.

This being settled, let us observe that the axis of the motion of circumduction of the thigh is evidently a straight line, obliquely directed from the head to the condyles, and distant consequently above from the axis of the bone, the whole length of the neck. Now, from what has just been said, it is evident, that the difficulty of circumduction will be in the direct ratio of the length

of the neck, and consequently very great. In the humerus, on the contrary, the neck being very short, the axis of the bone and that of the motion are almost the same; hence the facility and extent of the circumduction. We might fix precisely the relation of these motions by this proportion; the circumduction of the humerus is to that of the femur, as the length of the neck of the humerus is to the length of the neck of the femur; which shows us how much more difficult the circumduction of the femur is than that of the humerus. To know this, it is sufficient in fact to know the excess of the length of the neck of the first over that of the second.

It is easy to perceive the advantages of this very great extent in the circumduction of the superior limbs destined to seize, and of the limits placed by nature to that of the inferior limbs destined to standing and locomotion. We understand also why luxations are more easy in the first than in the second. The displacement almost always takes place in fact, in one of the simple motions, the succession of which forms the compound motion of circumduction, for example, in elevation or depression, in adduction or abduction, &c. Now all these motions being carried much further in the humerus than in the femur, the surfaces are more easily separated.

Second Genus.

This genus differs from the first by the absence of the motion of rotation. Opposition and circumduction are alone met with in it. We find examples of it in the temporal maxillary, sterno-clavicular, radio-carpal, metacarpo-phalangeal articulations, &c.

The want of rotation evidently supposes, from what has been said above, the absence of an osseous head, the axis of which would make, as in the preceding genus, an angle with the axis of the body of the bone. Thus in all the bones of the articulations that I have just mentioned,

the articular surface is at the extremity even of the bone, and not upon the side ; the axis is the same in both cases. They form a rectilinear lever, instead of an angular one.

The articular surfaces are in general, as in the preceding case, uniform, without eminences and reciprocal depressions; which would embarrass and even prevent circumduction. In the bone which serves for support, there is a cavity more or less deep; in the bone which is moved, there is an analogous convexity. The corresponding surfaces of the temporal and the inferior maxillary bone, of the bones of the metacarpus and the first phalanges, are examples of this arrangement.

This articular mode is the most favourably disposed for circumduction, which is, as we have seen, constantly in the inverse ratio of rotation, and which consequently has the greatest possible facility when the lever is rectilinear, a circumstance that destroys rotation. Yet in many articulations of this genus, circumduction is evidently less extensive than in the humerus and the femur ; but this arises from the arrangement of the moving powers which being in much greater number in the articulations of these two bones, compensate for the bad arrangement of the articular surfaces for circumduction.

In the genus of articulations of which we are treating, there is always one direction in which the motion of opposition is more easy than in the others; for example, it is elevation and depression in the jaw, flexion and extension in the first phalanges, in the wrist, &c. In general there are two lateral ligaments and the capsule in the direction in which the motions are most limited, the capsule only in that in which they are the most extensive.

Third Genus.

As we advance in the examination of these articular genera, the extent of their motion diminishes. This has

less opposition in many directions than the preceding, and less circumduction which always supposes an extensive opposition. Here this opposition is always limited to one direction only, to that of flexion and extension, for example.

We find this articular genus especially in the middle of the limbs, as at the elbow, the knee, the middle of the fingers in the articulations of the phalanges. Though the bone which composes them, inferiorly can move by itself but in one direction, yet it borrows from the loose motions of the superior articulation of the limb, so as to be able to be turned in every way.

The articular surfaces are found here as in the preceding genus, at the extremity of the bone, having the same axis as the bone; but they differ, 1st, in this that there are many eminences and cavities fitted to each other, an arrangement, which, by permitting the motion in one direction, prevents it in the others. Very commonly there are two kinds of round prominences, called condyles, which roll from before behind, or from without within, &c. upon two analogous cavities, that are separated by an eminence, which is received in the space between the condyles, as we see in the femoro-tibial, phalangeal articulations, &c. 2d. The breadth of the surfaces also distinguishes this genus from the preceding; this breadth insures its solidity, and prevents luxations, which besides are more to be feared when they happen here where more ligaments must be broken than elsewhere.

There is always in this genus greater extent of motion on one side, than on the opposite. In general flexion has always more extended limits than extension; observe in fact the condyles of the femur, of the phalanges, &c. they are extended much further in the first than the second direction; why? because all our principal motions are those of flexion, and the motions of extension are as it

were but to moderate the first, and have for their object only to bring back the limb to the position from which it can be bent again. Hence why the number, and the strength of the fibres are much greater in the flexors than in the extensors ; why the great vascular and nervous trunks are always on the side of flexion, as we see in the thigh, the leg, the fore-arm, the phalanges, &c. There is always something which limits the motion of extension, as the olecranon in the humero-cubital articulation, the crucial ligaments in the femoro-tibial articulation.

Though in the genus which we are describing, there is no well marked motion of circumduction, yet when the leg or the fore-arm are in flexion, they can move laterally and even in the form of a cone, but not in a very evident manner. In extension this is impossible, because the lateral ligaments being much stretched, do not yield enough to allow the bone to incline from one side to the other.

Fourth Genus.

Every kind of opposition and circumduction is wanting in this genus, which presents rotation alone, as we see in the articulations of the ulna with the radius, and the atlas with the odontoid process. Sometimes it is a concave surface rolling upon a convex one, as at the lower end of the radius, and at the odontoid process; sometimes it is a convex surface moving upon a concave one, as at the head of the radius ; there is always a kind of ligament which completes the concave surface, and which thus forms a ring turning upon the bone, or in which the bone turns.

Luxations are here very difficult, because the rotation being made upon the axis of the bone, the ligaments are hardly more distended on one side than the other, and are hence broken with difficulty, whatever may be the extent of the motion. The inferior part of the radius

forms a slight exception to this rule, because it is upon the ulna, and not exactly upon its own axis, that the bone turns in this place.

There is no rotation in the leg as in the fore-arm, because, as we have seen, that of the thigh which is very extensive, supplies the place of it; which the humerus could hardly do for the fore-arm, as we know when this last is anchylozed.

Fifth Genus.

Every kind of rotation, opposition and circumduction are wanting in this genus, which is the most numerous, and which embraces the articulations of the carpus, the metacarpus, the tarsus and metatarsus, of the vertebræ between themselves by their articular processes, of the atlas with the occiput, of the humeral extremity of the clavicle, the sternal of the ribs, and the superior of the fibula. There is only a kind of slipping more or less obscure, and in which the osseous surfaces hardly ever leave each other. These surfaces are almost all plain, very close together, united by a considerable number of ligaments, and so strong in their connexion, that luxations hardly ever happen to them. Another reason moreover which renders them difficult, is that all this genus of articulations belongs almost wholly to short bones; now we know, that the motion imparted to a bone has a power of action which is in direct ratio of its length, and in the inverse of its smallness; for example, the same power applied to the tibial extremity of the femur, would luxate much more easily the ischiatic extremity, than if it acted upon the middle of this bone.

As the separate motion of each of the articulations of the fifth genus is almost nothing, nature usually unites several at the same place, for the purpose of producing a sensible, general motion, as we see in the carpus, the tarsus, the vertebræ, &c.: this is also a reason of the dif-

ficulty there is in luxating this genus of articulations. In fact, how great the general motions may be, two bones, taken separately, move but little upon each other; now it is only the extent of the motion of the two separate bones from each other, that can produce the displacement.

III. *Observations upon the Immoveable Articulations.*

We have only pointed out orders in this class, because its varieties are not sufficiently great to assign genera for them.

1st. The order of immoveable articulations with surfaces in juxta-position, is met with where the mechanism of the part alone is almost sufficient to insure the solidity of the bones which are found only placed at the side of each other, without holding by any insertion, and having only between them a slight cartilaginous layer; the superior maxillary bones, wedged in between the malar bones, the ossa ungues, the ethmoid, the ossa palati, the vomer, and the frontal bone, are supported more by the general mechanism of the face, than by any articular attachments that unite them to each other; thus the squamous portion of the temporal bone supports the parietal, more by the abutting arches, than by the manner of the union of their respective surfaces. Remove this general mechanism of the part, you will soon see all the articulations separate.

2d. The order of immoveable articulations with inserted surfaces, owes also in some measure its solidity to the general mechanism of the part; but this mechanism would be insufficient to insure this solidity; thus the bones, instead of having almost plain surfaces, exhibit very evident prominences and depressions which are inserted into each other, as we see in the articulations of the parietal bones with each other, with the sphenoid, the occipital, the frontal, &c.; these are called sutures.

This order sometimes approximates the preceding, as in the union of the parietal and frontal bones, which, reciprocally aiding each other, are supported by this mechanism, more than by their insertions; sometimes it resembles the following order, as in the articulation of the occipital and parietal bones, in which the very deep insertions almost alone insure the solidity of the union. This order is never seen except upon the edges of the flat bones; the insertion of these edges compensates for their want of size, by multiplying the points of contact. The eminences and depressions forming the insertion are always of an irregular form and size. They are exactly fitted to each other, they are not alike in two bones of the same species, taken from two different subjects; so that we cannot unite to a detached left parietal bone, the right parietal bone of another individual. There has been much dispute upon the formation of the sutures; they are an effect of the laws of ossification, an effect which we can account for no more than we can for all the others, and all the general phenomena of growth; we shall see the progress they follow in this formation. This articular order is gradually effaced with age, and the bones unite together by the ossification of the thin intermediate cartilage. It is more rare that the preceding order disappears. I have seen, however, in extreme old age, different articulations of this order cease to be evident, those of the maxillary bones between themselves especially.

3d. The order of articulations with implanted surfaces borrows none of its solidity from the mechanism of the part; it owes it entirely to the relation of the surfaces, which are so united and embraced by each other, that displacement is impossible. There is but one example of this articular order, it is the teeth with the jaws.

Age does not here efface the articulation, and thus confound the two bones as in the preceding orders, because

the medium of union is the palatine membrane, which belongs to the mucous system, and which by its organization has no tendency to ossification ; whereas in the preceding cases, the intermediate cartilage has a natural disposition to become encrusted with the phosphate of lime.

IV. *Of the Means of Union between the Articular Surfaces.*

The articular surfaces would soon separate, if different organs did not retain them in place. These organs are the cartilages and the membranes for the immoveable articulations, the ligaments and the muscles for the moveable.

Union of the Immoveable Articulations.

The two first orders of immoveable articulations, those with inserted surfaces and those with surfaces in juxtaposition, have cartilages between the osseous surfaces, the breadth and thickness of which are found so much the greater in proportion as they are examined in subjects nearest infancy. Almost all the bones of the head are held together in this manner, which allows them to yield a little, and consequently prevents their fracture.

In the articulations of the pelvis, there are besides the cartilages, ligaments ; but as these articulations perform in certain cases small sliding motions, we can consider them as intermediate between the moveable and immoveable articulations ; it is on this account that they have the two kinds of organs especially destined to strengthen the articular surfaces of each of the classes, viz. the cartilages and the ligaments.

The immoveable articulations with implanted surfaces, an order which comprehends only the teeth, have nothing between the surfaces as a means of union, but a mucous membrane, the palatine. Hence why in the swellings of this membrane, in scorbutic affections, after the use of mercury, &c. the teeth become loose.

Union of the Moveable Articulations.

The moveable articulations with contiguous surfaces have the ligaments especially as a means of union, which are found in the five genera, but under different forms which will be examined hereafter. This kind of organ unites much suppleness with great resistance, a double attribute which it derives from its peculiar texture, and which renders it very proper for this function. Let us observe however that these two properties are in an inverse ratio in the two extreme ages of life, that suppleness is the companion of infancy, that stiffness and resistance are the character of the ligaments in old age. Hence in part the multiplicity of motions in one age, and their slowness and difficulty in the other.

The cartilages are not in this articular order, as in the preceding, means of union, but means of motion, by their smooth and polished surfaces.

As to the synovial membrane that is found exclusively in this order, such is its extreme tenuity, that it can hardly be considered as uniting the surfaces, and its use appears to be confined to the exhalation of synovia.

It is not the same with the muscles; they can be considered as forming at the same time around the moveable articulations, a power for the whole of the bone, and a resistance for its extremities, which they prevent from being displaced, by forming around them supports, the efficiency of which is in proportion to the efforts that are made to displace these extremities. In fact, it is in the great motions that these efforts are the most considerable; now then the neighbouring muscles of articulation strongly contracted, hard during their contractions, have a powerful tendency to prevent the osseous extremity from abandoning that which corresponds with it. In rest when the relaxed muscles offer but little resistance, the effort for support is nothing. A paralyzed limb can be

luxated much more easily than another, by external violence.

The order of moveable articulations with contiguous surfaces, has as a means of union, a substance, the nature of which is between that of the ligaments and that of the cartilages.

ARTICLE FIFTH.

DEVELOPMENT OF THE OSSEOUS SYSTEM.

There is no system in which anatomists have traced in a more accurate manner than in this, the different states in the different periods of life. The remarkable difference of a bone examined in the first months when gelatine almost alone composes it, compared with a bone of an adult in which the calcareous substance predominates, has especially arrested their attention upon this point. Let us examine the phenomena of ossification in all the ages; these phenomena should be considered during and after growth. In general, while this continues, there are some portions of the osseous system not ossified, as the neck of the femur, for example; ossification is not complete, the bones are not perfectly developed until towards the sixteenth or eighteenth year, and sometimes even later.

I. *State of the Osseous System during Growth.*

We commonly distinguish three states in the development of the bones, viz. the mucous, the cartilaginous and the osseous states.

Mucous State.

The mucous state may be considered as existing at two periods: 1st. In the first days of the development of the

embryo, a period in which the whole of its organs forms only a homogeneous and mucous mass, in which it is not possible to distinguish any line of demarcation, and in which the parenchymas of nutrition alone exist. All the organs are then of the same nature; the bones are in fact mucous like all the other organs, if by this word we understand a state in which the cellular texture existing alone with the vessels and the nerves, is penetrated by so large a quantity of juices, that it has the form of a mucilage, and gives the appearance of it to the embryo. 2d. We may understand by the words mucous state, that more advanced period of osseous nutrition, in which the bones can be already distinguished, seen through the transparency that the other parts of the limb still have, and in which they have a consistence much greater than that of the parts which surround them; now this state is only the commencement of that of cartilage; for the parenchyma of nutrition takes the cartilaginous character when it begins to be penetrated by gelatine, and it is in fact penetrated by this substance when it has more consistence, since it is that which gives it this consistence, and hence an existence distinct from the surrounding parts. If in the early periods, this cartilage is softer, if it flattens under the finger when pressed, if it even has an appearance partly mucous, it is because the gelatine is not yet in sufficiently large proportion, and because the nutritive parenchyma still predominates; gradually its quantity increases, and then the cartilaginous nature is more evidently developed.

It follows hence that the bones have three periods in their development; one is common to them with all the other organs; it is the mucous period; the two others especially characterize them; these are the cartilaginous and osseous periods. Let us examine their phenomena.

Cartilaginous State.

All the bones are cartilaginous before taking their last form. This state of cartilage begins at a period that is difficult to be determined; it is when on the one hand the circulating system begins to carry gelatine and present it to the organs, and when on the other the organic sensibility of the parenchyma of nutrition of the bones is put in relation with this substance. Then the consistence of the bone is constantly increasing, because the gelatine is constantly accumulating; now it accumulates in the same direction that the phosphate of lime afterwards takes; that is to say, in the long bones it is in the middle of the body, in the flat bones it is in the centre, and in the short ones it is in the centre also, that this substance is at first exhaled, which afterwards extends gradually to the extremities of the first, the circumference of the second and the surface of the third. I would observe however that we do not see, during the formation of the cartilaginous bone, those longitudinal striæ in the long bones, radiated ones in the flat, irregularly crossed ones in the short, which distinguish the osseous state in its formation, and which seem to indicate to the eye the course of the phosphate of lime.

The cartilaginous state exhibits a peculiarity that distinguishes it from the osseous state; it is that all the bones that are to be afterwards united by means of cartilage, such as those of the cranium, the face, the vertebral column and the pelvis make only one piece; whilst all those that are to be held together by ligaments, whose articulations are consequently moveable, are found very distinct, as the femur, the tibia, the clavicle, &c.

The broad bones, those of the cranium especially, do not exhibit in so distinct a manner the cartilaginous state. Their appearance, at this period of ossification, is even rather membranous. It arises from this; as they are

found interposed between the periosteum and the dura mater, and as their tenuity is very great, we can with difficulty distinguish them on the interior of these two membranes. But when we dissect the parts with care, we can distinguish the bone yet soft, from this double covering.

The cartilaginous state appears in the clavicle, the scapula, the ribs, before being discoverable in the other bones in which it is afterwards seen. When we examine the bones in this state, we find them of different consistence and solidity; where the exhalation of gelatine has commenced, they are incompletely cartilaginous; as we go from this point, they partake more or less of the mucous state. The cartilaginous bone has no internal cavity, no medullary system, &c.

Osseous State.

When the whole bone is cartilaginous, and even when some points appear to be still mucous, the exhalation of calcareous substance begins, and then the osseous state manifests itself; the following is the manner; the bone becomes more dense, then of a deeper colour, and finally of a very evident yellow in its middle, that is to say where the ossification should begin; gradually a red point appears; these are the vessels that begin to receive the red portion of the blood, and not to be developed as some anatomists pretend, to be hollowed out according to their expression, by the force of the impulse of the heart. They always existed; the white fluids alone penetrated them before, then the red globules are admitted into them. At the same time the neighbouring parts are encrusted with calcareous substance. This period is then remarkable in two particulars, viz. in respect to the entrance of the blood into the cartilaginous bone, and in regard to the exhalation of the phosphate of lime. These two phenomena are always inseparable; when there is redness in

one part of the cartilages, there are also osseous points; this is observed not only in common ossification, but also in those which are not so, such as the ossifications of the cartilages of the larynx, of the ribs, &c. When we examine the progress of the exhalation of the earthy substance, we see always in the bones, whether long, flat or short, a very red vascular layer, between the cartilage and the portion of ossified bone. This layer seems to serve as a precursor to the osseous state. Why do the vessels of the bones which before had admitted only white fluids, receive then red globules? It is not, as Boerhaave would have said, had he treated of ossification, because their caliber increases, but because the sum of their organic sensibility increasing, they are then found in relation with the red portion, which until then was foreign to them. Their caliber might be treble or quadruple the diameter of the red globules, but these would not enter if the organic sensibility repelled them, as the larynx rises against a body which attempts to enter it, though this body may be infinitely less than the glottis. It is by an increase of organic sensibility, that must also be explained how the bone, until then a stranger to calcareous substance, being in relation only with the gelatine, appropriates also to itself the first of these substances, and is penetrated with ease.

I will observe only that there is this difference between the exhalation of the two, that the first comes immediately from the red portion of the blood, since wherever it is deposited, there is, as I have said, blood vessels; whilst the second appears to come immediately from the white fluids, since the vessels of the tendons, the cartilages and the other parts that they nourish, do not evidently receive in their natural state any red globules, and all that circulates in them appears to be white.

The osseous state commences with the end of the first month in the clavicle, the ribs, &c.; it is a little more

slow in the other bones; we know not its precise period. The following is its progress in the three kinds of bones.

Progress of the Osseous State in the Long Bones.

We distinguish at first in the middle of these bones, a small osseous cylinder, very slender in its centre, enlarging towards the extremities, hollow in the interior for the rudiments of the medullary system, perforated by a nourishing foramen whose size is then in proportion very great, receiving also a very large vessel. This osseous cylinder, at first very slender in comparison with the cartilaginous extremities of the bone, is in a very evident disproportion to them in this respect; it is formed of very delicate fibres, and is gradually enlarged and extended, until it reaches near the extremities where it is found at birth; the most of these extremities are not then bony. Some time after, and at a period which varies in the different bones, there is developed in these extremities an osseous point which begins at the centre, and which is always preceded by the passage of the blood in the vessels. These new germs increase at the expense of the cartilage which is gradually lessened between the body and the extremity of the bone; at the end of some time there remains only a slight partition which ossification also seizes upon; so that the bone is then wholly osseous from one extremity to the other. The secondary points which are developed in the different apophyses, also unite; so that its substance is everywhere homogeneous. It is not until the age of sixteen or eighteen years, that nature has completely finished this work.

Progress of the Osseous State in the Broad Bones.

The mode of origin of ossification varies in this kind of bones. Those which are symmetrical, have always two points or more, which correspond upon each side of the median line; sometimes one of them is found upon

this line. When these points of ossification are in equal number, they are always upon the sides; if they are in unequal number, one of them is upon the line.

The irregular bones sometimes have but one of them, as in the parietal; at other times many appear in them, as in the temporal; but there is never a similar arrangement among them; only they correspond with those of the opposite bone.

At the first point of ossification in a broad bone, we perceive at first reddish spots, then we observe the phosphate of lime spreading in rays from the centre to the circumference of the bone. The osseous rays are very evident upon the bones of the cranium. Portions not ossified at first fill their interstices, which new rays afterwards occupy. All terminate in an unequal manner, without touching, so that by separating an ossified portion of a broad bone from the membranous portion to which it belongs, its circumference looks cut like the extremity of a comb; hence, as we shall see, the origin of sutures.

The delicacy of these bones is extreme in the early periods; they have not then any of the texture of the cells. At birth but few of the osseous centres are yet united; cartilaginous and membranous spaces separate them; these spaces are greater towards the angles than towards the edges, and generally at points the most distant from the primitive osseous centres. The bones with many points of ossification are formed of separate pieces, more or less distant from each other. Those with one point only, have but one piece.

After birth these bones extend more and more, their thickness and hardness increase; they are divided into two compact layers, the space between which is filled by the texture of the cells; gradually they touch at their edges, and then the sutures are formed in the cranium; for there is this difference between their ossification and

that of the long bones, that it takes place always from the centre to the circumference, and that new osseous points are not developed at the circumference to meet those of the centre. But when this happens, the union does not then take place as in the long bones, but sutures are formed ; and it is this which occasions the ossa wormiana, which are so much the larger as the osseous point is the sooner developed, because it has had time to extend itself more, before meeting the general ossification of the bone.

When a broad bone is developed by many points and there exists upon its surface an articular surface, it is usually the centre in which all the points unite at the period in which ossification terminates ; we see this in the cotyloid cavity, in the condyle of the occipital bone, &c.

There is often in the broad bones two well marked periods for their ossification ; it is so in those which, like the sacrum and sternum, are developed by a great number of points. These points begin at first to unite into three or four principal pieces which divide the bone ; this is the first period ; then much later, the union of the pieces takes place ; this is the second period.

Progress of the Osseous State in the Short Bones.

The short bones remain in general longer cartilaginous than the others. Often at birth many are still so, those of the tarsus and carpus in particular. The body of the vertebræ is ossified sooner ; a point is developed at the centre, and extends over the whole surface.

These phenomena are nearly analogous to those of the ossification of the extremities of the long bones, which the short bones resemble so much. After birth, the whole cartilaginous portion, is, if we may so say, invaded by the calcareous substance, which mixes with it, and there is finally only the articular cartilages left.

There are bones, as the occipital and sphenoid, which partake of the character of the broad and short bones :

their ossification is mixed, and follows the mode of one or the other, according to the part of the bone that we examine.

II. *State of the Osseous System after its Growth.*

The bones, having become completely ossified, continue to undergo different phenomena which anatomists have too much neglected. The general growth in height is terminated when ossification is complete ; and it even appears that the term of these two is nearly the same ; but that in breadth continues for a long time after ; compare the small and slender body of a young man of eighteen years, with the stout and well proportioned one of a man of forty, and you will see the difference. The bones follow the general law ; their nutrition is prolonged for their thickness, when that for their length ceases. It appears that then the vessels which penetrate by the foramina of the first and second order, do not contribute to this nutrition, which draws its materials from those of the third ; now, as we know that these very superficial vessels are arrested in the external fibres of the bone, and do not penetrate within, we understand, 1st, how, the growth going on without, the bone increases in thickness ; 2d, how this increase takes place especially on the compact texture, the proportional thickness of which is in the direct ratio of the age, as we may see by inspecting the different bones of the child, the adult and the old person.

This external growth has made it believed that the periosteum contributes to it especially by the ossification of its layers ; but we shall see in the article upon this membrane, what opinion should be entertained upon this subject.

It is principally at this period in which the work of nutrition seems spread upon the osseous surface, that the different eminences, which are scattered over this surface,

become more evident; then especially all the prominences of insertion become more prominent; there is in respect to these eminences a remarkable difference between the skeleton of a child and that of a full grown man. In the fœtus they hardly exist, as we see particularly by the different apophyses of the vertebræ, the spinous especially. As these eminences are generally the most distant parts from the primitive osseous centres, it appears that it is to this circumstance that must be attributed the slowness of their formation, since ossification always goes from points where it begins, to the most distant ones.

When the bone has all its dimensions it still continues to be the seat of a very active nutrition; exhalation constantly brings to it gelatinous and calcareous substances which absorption afterwards takes up; so that it is continually composed and recomposed. The experiment with madder evidently proves this; if we feed an animal for some time upon this, the bones become red much more easily, in proportion as the animal is younger; so that by amputating a limb after some time, the bones have an appearance wholly different from what is natural to them; if, after this amputation, we discontinue the use of the madder for some time, and then amputate another limb, the bones will be found to have entirely resumed their natural colour; now we know that the calcareous substance is the vehicle of the colouring matter, since while the bones are only cartilaginous the madder has no effect upon them. The calcareous substance is then alternately furnished and taken away from the bones. Besides, the formation and resolution of exostoses, the softening and brittleness of the bones, the phenomena of the production of callus, &c. are they not an evident proof of the exhalation and absorption of this principle? It appears clearly that the urinary system is the way by which nature gets rid of the calcareous and even of the gelatinous substance. It would be curious to

analyze accurately the urine of ricketty patients, and that of those affected with cancer ; it is probable that the first of these substances predominates in the urine of the first, and the second in that of the others ; I know of no positive experiments upon the subject.

Can we, by giving to patients gelatine or the phosphate of lime, restore to their bones the suppleness or solidity which they have lost ? No, because it is necessary not only to introduce these substances into the economy but also to restore to the bones their peculiar organic sensibility which they no longer have, and which, by placing these substances in relation to them, would enable them to appropriate these to their own nourishment. The blood might be loaded with earthy and gelatinous principles, and the bones would repel these principles, so long as their sensibility was not in relation with them.

The double motion of nutrition continues always in the bones, as we advance in age ; but its proportions change. The gelatine is constantly diminishing and the calcareous substance constantly increasing. Finally, in extreme old age this last predominates so much, that it would destroy their life, if general death did not take place before that of the bones.

It is to this that must be attributed the greyish colour that these organs then take ; hence also their constantly increasing weight ; hence consequently the difficulty of the motions of the limbs, since at the same time that the force of the muscular powers is diminished by age, the osseous resistance which they have to overcome increases.

At this period of life, the calcareous substance predominates so much in the economy, that it is thrown upon different organs, such as the arteries, the cartilages, the tendons, which then take the osseous character. We might say that by accumulating in our parts this substance foreign to life, nature wishes to prepare them insensibly for death.

In general, it is those organs whose nutritive substance is gelatine, which have the greatest tendency to be placed in relation with the calcareous substance, and consequently to be encrusted with it. Hence why the cartilages especially are ossified; why those of the sutures disappearing, the bones of the cranium become continuous; why the larynx is finally almost all osseous; why the cartilages of the ribs are often as solid as the ribs themselves; why oftentimes many vertebræ united form a more or less considerable continuous mass. I would observe however that the arteries, which have so great a tendency to ossification, are not so evidently gelatinous as many other substances which ossify much less easily, as the tendons for example.

III. *Peculiar Phenomena of the Development of the Callus.*

Nothing is easier after what has been said upon the osseous nutrition, than to understand the formation of the callus. We know that it has three periods, 1st, the development of the fleshy granulations; 2d, their change into cartilage; 3d, the change of this cartilage into bone. This triple phenomenon takes place in a space of time that varies according to the age, the fracture, the kind of bone, &c. but which is in general longer than that of the other cicatrices.

The development of fleshy granulations is a phenomenon common to every species of organ which has experienced a solution of continuity and whose divided edges are not in immediate contact. Here these granulations arise from every part of the divided surface, from the periosteum, the compact texture and that of the cells, the last especially. Those of one side unite to those of the opposite. Thus far the osseous cicatrix does not differ from that of the othe parts. This state corresponds with the mucous state of natural ossification. As the fleshy

fibres are but the extension of the nutritive parenchyma, they have its vital forces; their organic sensibility follows the same laws as in ordinary nutrition; at first it is in relation with gelatine; this is then exhaled; then commences the cartilaginous state; then the osseous cicatrix takes a peculiar character, which distinguishes it from that of the other organs.

At the end of a longer time, the organic sensibility increases in the parenchyma of cicatrization which the fleshy granulations form; then these become in relation with the calcareous substance which comes to the bone, and which they had until then repelled; they admit it then, as well as the red portion of the blood which always precedes it in every species of ossification.

Hence we see that the callus is cellular and vascular in the first period; that in the second it contains cellular texture and vessels, with gelatine; that in the third, it has cellular texture, vessels, and gelatine, with calcareous substance.

It has not the regular forms of the sound bone, because the parenchyma of cicatrization arising irregularly upon the osseous surfaces, the exhalation and absorption of gelatine cannot be made in a precise and regular manner. The callus is so much the larger in proportion to the separation of the ends of the bone, because the fleshy granulations having had more space to go over in order to meet, are more extensive, and consequently have absorbed more nutritive substance.

If the constant motion of the fractured ends prevents on each side the granulations, or what is the same thing, the two parenchymas of cicatrization from uniting, then, notwithstanding the exhalation of the nutritive substances in each of them, the bone does not unite, and hence the preternatural articulations.

Callus is formed with difficulty when the ends divided and laid bare, suppurate with the neighbouring parts, as

happens in compound fractures, because the formation of pus expends the nutritive substances destined to repair the fracture. The further considerations upon this singular production belong to pathology.

I have not exposed in this chapter the ideas of the ancients, who thought that the bones were formed by the hardening of an osseous juice, the existence of which there is nothing to demonstrate; nor those of Haller, who imagined that the heart hollowed out arterial channels in the osseous substance by its own impulse, and hardened this substance by the pulsation of the arteries; nor those of Duhamel, who made every thing depend upon the periosteum; I refer to various works that have a thousand times refuted these opinions.

Without refuting any one in particular, I would remark that they have one fundamental error, viz. that of considering osseous nutrition in an insulated manner, of not presenting it as a division of general nutrition, of admitting for its explanation reasonings only applicable to the bones, and which are not derived as consequences from those which serve to establish the nutrition of all the organs. Let us never lose sight of this essential principle, upon which rest all the phenomena of the economy, viz. that over a multitude of effects, a very small number of causes only presides. Let us mistrust every explanation which is partial and mutilated, which circumscribes the resources of nature according to the limits of our weak understandings.

IV. *Peculiar Phenomena of the Development of the Teeth.*

The teeth, differing in part by their texture, from the other bones, have also a peculiar mode of nutrition which we shall now examine. But as the knowledge of this supposes that of the general structure of the teeth, it is proper to explain here that structure, referring

their description to the examination of the bones of the face.

Organization of the Teeth.

The teeth are formed by two substances, one external, of a peculiar nature, called enamel, the other internal, which is the common base of it, and the texture of which is the same as that of the other bones. They have besides a cavity which contains a spongy substance, as yet but little known.

Hard Portion of the Teeth.

The enamel of the tooth is only seen around the crown; some anatomists have thought that it extended a little upon the root, an opinion founded no doubt upon the extreme whiteness that the root often has in detached teeth, and which makes it impossible to distinguish the line of demarcation. But a very simple experiment proves this demarcation; it consists in macerating the tooth in diluted nitric acid. The acid immediately attacks both the root and the crown which it softens; but the first becomes yellow like almost all animal substances exposed to its action, whilst the other preserves its colour, and even becomes whiter. This experiment also proves that their respective natures are essentially different.

The enamel, thick on the top of the crown, grows thinner towards the root, an arrangement required by its use, which is to defend the tooth, to support principally the efforts of mastication, which are made especially upon the top of the crown.

This substance hard, compact, particularly when it has remained a long time in the air, acted upon with difficulty by the file, is composed of very close fibres, the direction of which cannot be traced. The medullary oil does not appear to penetrate it; it does not burn, but

breaks by the action of fire, and is thus separated from the other substance, which, exposed to heat, at first becomes black, then burns like the other bones and gives out the same odour.

Is the enamel organized, or is it only a fluid which, oozing at first from the external surface of the tooth, afterwards becomes there hardened and concrete? This question is not I think easy to be resolved. The enamel has in fact attributes which seem equally favourable to both these opinions. On the one hand it is sensible, like every thing that is organized; it gives us, much more evidently than the hair or the nails, the sensation of bodies which strike it. The diluted acids, the vegetable especially, raise its sensibility so much, that the least touch becomes very painful a long time after their use. The teeth are then, as we call it, on edge. On the other hand the enamel has many characters that seem to denote a want of organization. 1st. It never inflames, or becomes the seat of any tumour, or any alteration which softens its texture; it never experiences any alteration, which by raising its life, renders it more sensible than in a natural state, as happens to the hair, for example, which ordinarily insensible, has a very great vital activity in the plica polonica. In fact we often judge of the vitality of organs more by their morbid alterations, than by their natural state. 2d. It appears that there does not take place in the enamel alternate exhalation and absorption of nutritive matters, or at least if it does, it is not sensible. Rubbing wears away this substance, which is never replaced; this is remarkable in old people, and in those who are in the habit of often striking their teeth together. We know that we file the enamel like an inorganic body, and that it is not reproduced, whilst the hair and the nails evidently grow after being cut. File the extremity of a long bone after amputation; fleshy granulations will soon grow upon the filed sur-

face; the action of the instrument will be a stimulus which will develop the vital phenomena.

The osseous portion of the tooth composes the whole of the root and the interior of the crown; it is formed by the compact texture, very dense, having great resemblance to that of stone. It has none of the texture of the cells. Its fibres, very close to each other, have various directions, very difficult to trace, but which in general follow that of the roots; it is necessary, in order to see this direction perfectly, to soften the teeth in an acid.

Each tooth has a cavity situated in the crown, of the same form as the crown, diminishing in diameter as we advance in age, communicating externally by small canals, the number of which is equal to that of the distinct roots of the tooth, and which open at the end of these roots. This cavity is lined by a very delicate membrane on which the vessels ramify, and which, with its opposite face, covers the marrow.

Soft Portion of the Tooth.

This is a spongy substance which appears to be formed by the interlacing of the vessels and nerves belonging to each tooth, but the nature of which is not yet well understood; we know only that it has a very great animal sensibility equal to that of the medullary organ. This is proved, 1st, by the pains of carious teeth in which the marrow is bare, and which are, as we know, extremely acute; 2d, by the introduction of a probe into the opening occasioned by caries, this produces no pain until it comes to the marrow, and then it is extreme; 3d, by opening a socket of a very young animal that has not yet cut its teeth. At this age the marrow is very considerable and the tooth being small in proportion, it is easy to raise the tooth without injuring it, because it has as yet no root and the opening at the base of the crown is very large. The tooth being raised and the marrow thus laid

bare, if it is irritated in any way the animal gives signs of the most acute pain. I have often made this experiment, always easily done, on account of the want of thickness of the osseous layers which then form the sockets.

The teeth have remarkable sympathies, which extend not only to the solid part, but also to the marrow. As this is much greater in proportion in the early ages, as it is almost the predominant part of the tooth, these sympathies are then more numerous and evident. In these sympathies, sometimes the animal and sometimes the organic properties are brought into action.

The sympathies of animal sensibility are evident in those pains of which the teeth become the seat from the action of cold or moisture upon the cutaneous system; in those produced in the face and the head by the caries of a tooth. Fauchart relates a case of obstinate hemicrania, which was immediately removed by the extraction of a tooth. The sensibility of the ear and the eyes is changed in some violent cases of tooth ache. The animal contractility is also brought into action in the sympathies of the teeth; nothing is more frequent in dentition, than convulsions of the voluntary muscles. Tissot speaks of a spasm of the muscles of the jaw, which was cured by the extraction of two carious teeth, and of a convulsion in the muscles of the neck that occasioned death, the primitive source of which was in a decayed tooth.

The organic sympathies are not less often produced by affections of the teeth. Spasmodic vomiting, diarrhoea, frequency of the pulse, oftentimes involuntary evacuation of urine, phenomena, over which the sensible organic contractility of the stomach, the intestines, the bladder and the heart presides, are the frequent effects of dentition and violent pains of the teeth, especially of the first. The insensible organic contractility, and the organic sensibility are brought sympathetically into action in the

enlargements of the parotid gland, in the general swelling of the face, in the increased secretion of saliva and sometimes in the erysipelatous inflammations which take place from an acute affection of the teeth.

The sympathies of the teeth often take place between the two corresponding teeth of the same row or of the two rows. My first upper molar tooth of the left side is a little carious; from time to time it gives me pain, then invariably the first molar tooth of the right side becomes as painful, though it is sound. There are other cases in which a tooth being painful below, sympathetic pains are felt in that which is above, and vice versa.

The structure of the teeth having been explained, let us see how their different substances are developed. This subject of osseous nutrition does not appear to me to have been clearly illustrated by any author. I shall attempt to explain it better. There are two dentitions, one is provisional and limited to the first age, the other belongs to the whole life; each should be considered before, during, and after the cutting of the teeth.

First Dentition considered before Cutting.

The phenomena of dentition before the period of cutting are these; the jaws of the fœtus are closed the whole length of their upper edge; they appear to be homogeneous at first view; but examined in their interior, they exhibit a row of small membranous follicles, separated by delicate partitions, disposed like the teeth of which they are to serve as the germ, and having the following arrangement.

The membrane which serves as a covering to the follicle forms a sac without an opening, which lines at first all the parietes of the socket, to which it is attached by elongations. At the place where the vessels and nerves enter, this sac leaves the socket, becomes detached, is folded into the form of a canal which accompanies the vascular and

nervous bundle, and afterwards spreads out upon the marrow of the tooth which is the termination of the bundle.

It follows from this that this membrane has the general conformation of the serous membranes, in the shape of some kinds of night-caps. It has two portions, the one attached and lining the socket, the other loose and covering the marrow, as for example, the pleura has a costal and a pulmonary portion. The marrow and the vessels, though contained in its duplicature, are in truth found without the cavity, which is lubricated by a simple exhalation. I have found that this exhalation was like that of the serous membranes, essentially of an albuminous nature ; the action of the nitric acid, that of alkohol and of fire incontestably prove it. Subjected to the action of one of these agents, especially the first, the membrane whitens immediately. The layer of albumen which covers it becomes concrete and coagulated, as when we make a similar experiment upon a serous surface.

The marrow, very considerable at this period, is found suspended, like a bunch of grapes, from the extremity of the vessels and the nerves.

It is upon the medullary portion of the membrane of the follicle, and upon the surface of its loose extremity, that the first osseous point is developed ; it soon extends, and takes precisely the form of the top of the crown, which it is afterwards to form, that is to say, that it is quadrilateral in the molar teeth, pointed in the canine, and wedge shaped in the incisors. Developed at first nearest the gums, it extends afterwards along the vascular and nervous stem, it is moulded upon it as it approaches the part of the alveolus where it enters ; so that it exhibits on this side a concave surface which embraces the pulpy portion of the membrane, and adheres by several vascular elongations ; and as this portion is loose, the first rudiment of the tooth floats also in the cavity of the

membrane, as we can see very well by cutting the alveolar portion of this membrane, after having destroyed the corresponding part of the alveolus.

The following consequences result from this kind of development; 1st. The crown is first formed, and the root is not produced but as the ossification in length advances upon the portion of membrane lining the vascular and nervous bundle. 2d. As all the vessels that come to the tooth enter at its internal surface, and as the external is entirely free in the cavity of the membrane, the ossification in thickness is made especially at the expense of the internal cavity which is constantly contracting, as well as the marrow, an arrangement, the reverse of that of the other bones, the ossification of which commences at a point placed in the centre of the cartilage, and which at first solid in the middle, afterwards become hollow for the medullary cavities and those of the cells, which are always enlarging. 3d. After the ossification of the tooth, the portion of the membrane of the follicle which lined the alveolus, remains the same, whilst that its portion corresponding with the marrow, originally free at the other side, becomes adherent on this side to the whole dental cavity which it lines, of which it forms the membrane noticed above in the article on the structure of the teeth, and which is thus found between the marrow and the osseous substance. 4th. The marrow of the tooth is the part first formed, and the most considerable in the first periods of life. It appears that the osseous substance is next formed, and that the enamel afterwards arises on the exterior of this. I have not yet been able to make evident the manner of its origin.

It is difficult to ascertain at what period the membraneous follicle is formed; that of the first ossification appears to be from the fourth to the fifth month. At the time of birth, we find the twenty teeth of the first dentition already advanced; the whole crown is formed; the

beginning of the root appears also in the form of a broad tube, with extremely delicate parietes, and which is constantly becoming longer and thicker; when it reaches the bottom of the socket, the tooth immediately appears externally as this is too narrow to contain it.

The number of teeth, less in the first than in the second dentition, gives a peculiar form to the jaws of the fœtus and the infant, especially to the lower one, which is less elongated in front, and consequently wider in proportion than in the adult, in whom in order to receive all the teeth, the alveolar border must necessarily be more extended. This arrangement of the lower jaw has a great influence in the expression of the physiognomy.

First Dentition considered at the period of Cutting.

The following phenomena take place about the sixth or seventh month after birth, very rarely sooner, still more rarely before birth, though there are examples of this, as is proved by the history of Louis XIV. At first the two small incisor teeth of the lower jaw appear, sometimes together, sometimes separately; soon after the corresponding incisors of the superior jaw. A month or two later, the four other incisors are cut. At the end of the first year. the four canine teeth usually appear. At the end of the second, or often later, two molar are cut in each jaw and two others soon follow. Each cutting almost always begins in the lower jaw. At the age of four years, four and a half, sometimes five or six, always at a very uncertain period, there appear below two other molars and then two above, which complete the number of twenty-four teeth forming the first dentition; all these except the last four fall out and are replaced by new ones.

The following is the mechanism of this first dentition; the ossification extending constantly towards the root, the tooth can no longer be contained in the socket; it pierces the alveolar portion of the membrane and the

mucous membrane of the mouth and an intermediate medullary texture that separates them, with much ease, as this triple layer gradually becomes thinner as the cutting approaches. Is this phenomenon owing only to the mechanical pressure of the tooth? I think that there is another cause; for observe that here the membranes are very little raised before rupturing; whilst that in polypi and other tumours that sometimes arise under the membrane of the gums, it is infinitely more stretched, still it does not break, but is only lifted up. The mechanism of the opening of the gums is not more known than the principle of the severe accidents which are sometimes connected with it. The sac which formed the original membrane of the follicle being thus open, its portion which lines the socket unites to the membrane of the mouth, becomes continuous with it and at the same time adheres intimately to the neck of the tooth; and as during the development of the root, the internal face of this membranous portion, at first loose as we have seen, has gradually contracted adhesions with it, it follows that this root is found fastened between the alveolar portion which lines its exterior, and the medullary portion which covers the interior; it is this which gives it solidity. As the adhesions of the membrane increase, we can less easily distinguish it. It is rare that in the first dentition the formation of the root is finished as completely as in the second; its internal cavity remains also very broad, and the marrow is more developed.

Second Dentition considered before Cutting.

It is necessary, as in the preceding case, to distinguish the nutritive phenomena into those which take place before, during and after the cutting. Before the cutting, we observe by opening the jaw, a row of dental follicles, corresponding to the row of teeth already formed, situated below or at the side, and separated from them by little

partitions, the thickness of which is found greater in proportion as it is examined nearer infancy.

These follicles have precisely the same arrangement as those of the first dentition; like them they form sacs without an opening, the alveolar portion of which is attached, and the loose medullary portion is covered on its surface with the first osseous layers for the crown. The manner of growth is the same; that is to say, it takes place from the exterior to the interior, the reverse of the other bones; an arrangement, which gives the part of the tooth immediately in contact with foreign bodies, being the first formed, time to acquire the solidity necessary for its functions.

As the second teeth grow, their vascular system becomes greater, and that of the old ones diminishes; which arises from this, that the sensibility weakened in the last, draws to them no more blood, whilst being raised in the others, it attracts it powerfully. We observe also that the partition of the sockets diminishes in thickness, and that the root of the first is destroyed. This double phenomenon does not appear to be owing to the pressure exerted by the new tooth, as then the root would spread and become flat only; or if it experienced a real destruction, we should find the remains of it, which we never do. It is then probable that it is by the absorption of the phosphate of lime, that the partition and root disappear, nearly as we have said the internal cavities of the cartilaginous bones are formed.

We see from this, that the ossification of the roots of the first teeth is of short duration; it begins the last and terminates the first. When it is of but little extent, the teeth become loose, from the want of insertion. The disappearance of the partitions increases it. It is at about the age of six or seven years that the shedding of them commences; this takes place in the order in which they were cut, that is to say, first the incisors, then the

canine, and then the molars. Observe that the last, which appeared at four years of age, are not renewed.

Second Dentition considered at the period of Cutting.

During the cutting of the second teeth, we observe them come out in the same order as those with which they correspond are detached. 1st. The eight incisors. 2d. The four canine appear. 3d. In the place of the first molar, two new ones are cut; these afterwards have the name of small molars. 4th. The second molar remains, as we have just said; it is the first of the great ones. 5th. At eight or nine years of age, two other molars appear in each jaw. 6th. Finally, at eighteen, twenty, or thirty years, and sometimes later, a third molar is cut; this is called the dens sapientiæ.

There is then in each jaw sixteen teeth, of which four are incisors, two canine, two small molars, and three large ones.

Sometimes the second teeth while they are forming, instead of appropriating to themselves the nutritive substance of the roots of the first and their partition, leave them untouched; neither are destroyed; and the second teeth are cut at the side of the first which remain in their places. When this phenomenon happens, it is usually only to a single tooth; sometimes, however, it happens to many and even all, and then there is a double row. In general, the second teeth have a tendency to go out at the side of the gums. When very obliquely placed, by a defect of conformation, their crown leans forward or backward; instead of piercing the jaw, they remain always buried in the sockets.

Phenomena subsequent to the Cutting of the Second Teeth.

After being cut, the teeth evidently grow, 1st, in length; 2d, in thickness. It is only the root that is en-

larged in the first direction ; the crown preserves always the same dimensions; and if in old people it appears longer, it is only because the gums have retracted ; a phenomenon which besides we very often observe in persons who have become thin, in those who have made use of mercury, &c.

The growth in the second direction is not made without, but only within ; the canal of the root and the cavity of the body are constantly contracting, and are finally obliterated. Then the tooth receiving no longer the blood or the influence of the nerves, dies and falls out. But this death appears also to be hastened by the accumulation of osseous substance, of a very great quantity of the phosphate of lime, which predominates there so much over the gelatine, that the principle of life is entirely destroyed, so that in this respect, the shedding of the teeth exhibits a phenomenon analogous to that of the shedding of the horns of the herbivorous animals, of the calcareous shell of the crustaceous ones, &c.

Why has nature given to the life of the teeth a shorter term than to that of the other bones, which do not cease to exist but with the other organs, whilst the teeth die a long time before? Is it because the stomach becoming weak with age, the animals are thence compelled to nourish themselves in their old age, with soft substances, adapted to the languid state of the gastric forces? Undoubtedly in man, a thousand causes, arising especially from the nature of the aliments, their degree of heat and cold, the manner in which they are cooked, their infinitely various qualities, hasten the natural period of the death and the fall of the teeth, because by incessantly exciting and stimulating these organs, they keep them in a state of constant activity, which exhausts their life sooner than it otherwise would have been. Thus a thousand causes arising from society, make the term of the general life much shorter than that fixed by nature. But

in general in all animals, the death of the teeth precedes that of the other organs, though they are not under the influence of society, and they masticate only aliments destined by nature to be in contact with their teeth.

The jaws destitute of teeth in old age, contract; the sockets are effaced; the texture of the gums becomes firmer, and mastication is continued, though with more difficulty. In this change of conformation, the alveolar edge is thrown back ; hence the prominence of the chin before. It diminishes in height; hence the approximation of this part to the nose, a phenomenon that arises especially from the absence of the teeth.

V. *Particular Phenomena of the Development of the Sesamoid Bones.*

The sesamoid bones exhibit a less marked exception than that of the teeth, to the general laws of ossification, but one, however, which is as real.

General Arrangement of the Sesamoid Bones.

These small bones, commonly of a round form, and of various size, do not usually exceed that of a pea, except however the patella; they are in general found only in the extremities; the trunk never has any of them.

In the superior extremities we hardly see them, except in the hand, in which the articulation of the thumb with the first bone of the metacarpus always presents two of them, and in which they are sometimes found in the analogous articulation of the index finger, rarely in that of the little one, or in the phalangeal articulation of the thumb.

In the inferior extremities on the contrary, they are numerous and especially much more evident. Two are seen on each condyle of the femur, in the tendons of the biceps, behind the knee ; in front is the patella. In the foot, the tendon of the tibialis posticus near its insertion

in the tuberosity of the scaphoid bone, that of the peroneus longus in its passage under the cuboid, have also sesamoid bones. We uniformly see two under the metatarso-phalangeal articulations of the great toe; under most of the analogous articulations of the other toes, they are also found, though they are more variable. In the phalangeal articulations I have also seen them many times. In general, the sesamoid bones exist only in the direction of flexion, which is that in which the greatest efforts to support are made. In the direction of extension I know no one but the patella.

These little bones have not, like the others, a separate existence; they are developed always in a fibrous organ, either in a tendon, as those of the biceps, the peroneus, the tibialis posticus, as also the patella; or in a ligament, as all those placed before the metacarpo-phalangeal articulations, the metatarso-phalangeal or phalangeal, which have for their basis the great transverse fibrous fascia, which we have called the anterior ligament of these articulations.

Fibro-Cartilaginous State.

The two primitive bases of the sesamoid bones remain for a long time without exhibiting any rudiments of them, and are at the place where these bones are to exist as they are everywhere else. Their organization is generally uniform. Some time after birth, a little more gelatine than would serve for the nutrition of these two fibrous bodies begins to be exhaled at the place where the sesamoid bones will hereafter be found; then arise cartilages, essentially different from the cartilages of ordinary ossification, which are nearly of the same nature as those of the extremities of the long bones of adults, whilst that these belong truly to the class of fibro-cartilaginous substances. They resemble in their nature the inter-articular fibro-cartilages, those of the tendinous

grooves, &c. These are not cartilages, but the fibro-cartilages of ossification, of which we distinguish so much better the fibrous base, as it is nearer the period of their development that we examine them.

Osseous State.

Gradually the vessels of these fibro-cartilages, which had only circulated white fluids, have their sensibility placed in relation with the blood; this fluid penetrates them; at the same time the phosphate of lime begins to be deposited in them; then the texture of the cells is formed in the interior by a mechanism analogous to that of the other bones; a delicate compact layer is developed on the exterior. But in the midst of this new bone, the fibrous base always remains; the fibres of the tendon, above the sesamoid, are continued, if we may so say, through its substance with those below it; thus the cicatrices of these bones, when they are fractured, have a peculiar and distinctive character; it is their fibrous base, which extending itself for their re-union, produces this difference. We know that the callus of the patella is not the same as that of the other bones. Often when the apparatus has not been exactly kept in place, there remains between the two fragments a fibro-cartilaginous texture as a means of union; now this texture is the development not only of the cartilaginous portion of the bone, but also of the portion of the tendon of the extensors, which makes part of the organization of this bone. The life of the sesamoid bones partakes almost as much of that of the fibrous as of that of the osseous system.

As we advance in age, these small bones increase and become more characterized in the animal economy; oftentimes they are developed very late, at the age of twenty, thirty, or even forty years. In some old people they are very large on the foot. I have seen the bodies of two persons subject to gout, in which they were so

developed as probably to interfere with motion. Was there any connexion between them and this severe affection? I know only these two facts.

The sesamoid bones elongate their tendons from the centre of motion, facilitate their sliding upon the bones, defend their articulations and even contribute to their motions. All those developed in the anterior ligaments of the metacarpo and metatarso-phalangeal articulations, and of the phalangeal themselves, contribute also to the motion of these articulations. A portion of the synovial membrane is spread upon their face that corresponds with it, and which remains slightly cartilaginous.

The formation of the sesamoid bones is not a mechanical effect of the pressure of the tendons or the ligaments against the bones, as has been said, but the result of the laws of ossification. In fact, in the first supposition, why should all the articulations of the hand and the foot, other than those pointed out above, being exposed to a motion nearly equal to the motion of these, be destitute of these bones?

MEDULLARY SYSTEM.

THOUGH the medullary system is only met with in the bones, and though its principal uses appear to relate entirely to them, yet its properties and life differ so much from the properties and life of these organs, that we are compelled to examine them in a separate manner.

We distinguish two kinds of medullary systems; one occupies the texture of the cells of the extremities of the long bones, and the whole of the interior of the short and flat bones; the other is found only in the middle part of the first; let us examine each separately.

ARTICLE FIRST.

MEDULLARY SYSTEM OF THE FLAT AND SHORT BONES, AND THE EXTREMITIES OF THE LONG ONES.

I. *Origin and Conformation.*

THIS system appears to be the expansion of the vessels which penetrate the bones through the foramina of the second order, that is to say, through those that go to the common texture of the cells. These vessels having arriv-

ed on the internal surface of the cells, divide ad infinitum and anastomose in a thousand ways. Their interlacing gives to the interior of the texture of the cells that red appearance that characterises it, and which is so much the more evident, as it is examined at an age nearer infancy, because in fact the vascular system which is very evident at this period, becomes contracted and effaced as we recede from it.

These are the vessels which, in the section of the bones of the cranium by the trephine, give to the saw-dust the redness that is observed. It is these that produce the same phenomenon in the amputation of the extremity of the limbs. Though in general they remain loaded with blood at the moment of death, yet we can, as I have often done, accumulate in them still more by fine injections, which drive before them that which is found in the vessels, and concentrate it at their extremities; then the spongy texture of the adult is almost as red as that of the child which has not been prepared.

II. *Organization.*

Authors speak of a delicate membrane that lines the interior of all the osseous cells, and which they consider to be the exhalant organ of the medullary fluid. I have never been able, though my researches have been numerous, to discover a similar membrane. We see only the vascular elongations of which I have spoken, which, greatly multiplied, appear in fact to form a membrane, but when examined attentively are found to be very distinct from each other, not continuous, except at the place of the anastomoses, and leaving between them many small spaces in which the bone is not covered, but is in contact with the medullary fluid.

The exhalation then of this fluid appears to arise only from this vascular net-work, and in this respect it is anal-

ogous to that of the compact substance, which evidently contains no membrane, and the pores of which are however found filled with this medullary fluid, as is proved by the combustion of the compact texture and its exposure to the sun or artificial heat.

III. *Properties.*

This vascular net-work has only organic sensibility and insensible organic contractility, which are necessary for its functions ; and it is this which especially distinguishes it from the medullary system of the middle part of the long bones, whose animal sensibility is, as we shall see, very great. Irritate in a living animal the interior of a short or flat bone, or the extremity of a long one, no sign of animal sensibility is manifested. Sawing the cranium, the condyles of the femur and the head of the humerus is not painful.

Injuries of this system when they are very great may produce necrosis of the bone, and the formation of a new osseous substance at the expense of the periosteum ; but if a small portion only is affected, this phenomenon does not take place. I have many times perforated transversely with a gimblet the extremity of a long bone of an animal, and afterwards passed a red hot iron through the opening ; the animal has always recovered without necrosis ; the articulation has only remained swelled, and much injured in its motions, and some scales have come from it during the suppuration.

IV. *Development.*

The vascular net-work which forms this medullary system, exists in the cartilaginous state ; but then, on the one hand, it does not admit the red portion of the blood, and on the other, the interstices of its meshes are found

so filled with gelatine, that the cartilage appears homogeneous. At the period of ossification, the red blood penetrates on one side of these vessels, whilst on the other they become evident from the absorption of gelatine at the place of these cells, upon the internal surface of which they ramify.

In the fœtus and the first age, this medullary system has a remarkable arrangement. It contains scarcely any of this oily fluid, from which it borrows its name, and which afterwards fills in so great a proportion the interstices of the texture of the cells of the different bones; by examining these organs comparatively in the different ages, I easily convinced myself of this. 1st. Exposed to a considerable degree of heat, the texture of the cells of the bones of an adult has an abundance of oily fluid flow from them. From the same experiment in the fœtus, there only follows a drying of this texture by the evaporation of the fluids which enter it. 2d. If we burn the extremity of a long bone of an adult, the combustion is spontaneously supported by the oily fluid that escapes from the pores of the second species, and which keeps up the flame until it is exhausted. In the fœtus, the bone ceases to burn when we take it from the fire, because the fluids it contains do not support combustion. 3d. Nothing is more difficult than to keep the bones of the adult white, because the oil that is in their interstices always yellows them a little. In the fœtus and the infant, in whom this cause does not exist, the bones are easily kept white. 4th. By ebullition, we extract scarcely any oil from the texture of the cells in the first age; much swims on the water in which we have boiled this texture in the following ages. In general, the fœtus appears to want this oil entirely; it is formed after its birth, and its proportion is constantly increasing until complete growth. What fluid supplies its place in the first years? At first a large quantity of blood; for in general the redness of the medullary

system is in the inverse ratio of the oil that is found in it; but the interstices of the cells appear moreover to be moistened by a fluid with which we are unacquainted, and which evaporates, as I have said, when we expose to the fire the bones of a fœtus.

ARTICLE SECOND.

MEDULLARY SYSTEM OF THE MIDDLE OF THE LONG BONES.

This system differs essentially from the preceding in its nature, its properties, its functions, &c. It occupies the centre of the long bones, whose great cavity it fills.

I. *Conformation.*

Each of the organs from the whole of which it results, exhibits it under the form of a delicate membrane, lining the whole cavity, folded a great number of times, giving origin to many elongations, of which some cover the fine threads of the texture of the cells which are met with in this cavity, others pass, without adhering to any osseous portion, from one side of the membrane to the other, and of which all form numerous cells in which the marrow is contained.

We can then form of this organ an idea analogous to that which the cellular organ gives us; viz. that of a spongy body with communicating cells. The place that it occupies, gives to it as a whole, a cylindrical form.

It appears that at the two extremities of the canal, the cells or membranes do not open into those of the texture

of the cells, and that the medullary fluid of the preceding system does not communicate with the marrow of this. In fact, the line of demarcation which separates them is evident; they do not mix in a gradual manner. Air injected from one side of the medullary cylinder, only penetrates with difficulty and by tearing the membrane, into the texture of the cells of the opposite extremity of the bone; yet, notwithstanding these considerations, I confess that the question is not fully settled. The transudations in dead bodies have no influence in deciding it, on account of the permeability that our parts acquire after death.

II. *Organization.*

The texture of the medullary membrane is very little known, because its extreme tenuity conceals it from our researches; for it is only in the bones of ricketty subjects, that its morbid increase in thickness has permitted me to trace it accurately. It has the appearance of cellular texture; yet its properties and its nature are very different from this texture; it cannot be referred to any of the three classes of membranes, the serous, the fibrous or the mucous. Some have pretended that it was an expansion of the periosteum, which had passed through the numerous foramina by which the bone is perforated, and entered into the medullary cavity; but the least parallel made between these membranes is sufficient to make us see that they are essentially different in their functions, vital forces, &c. and cannot have the same texture. A principal vessel penetrates the medullary membrane; it is the artery, which enters by the only, but very large foramen, which is seen on the body of the long bones; the two branches of this artery and those of the corresponding vein, ramify in an opposite direction in the medullary cylinder, and by their innumerable branches give to it a

very evident reddish colour, that disappears with age. The extremities borrow their vessels from those of the neighbouring texture of the cells. We cannot trace any nerve there. Such is sometimes the abundance of the fluids which penetrate this membrane, and its extreme tenuity, that it might be said not to exist. To be convinced of its existence, expose the cylinder that it forms to the intense action of heat; it contracts, has the horny hardening immediately like all the solids, and thus becomes more apparent.

III. *Properties.*

The properties of texture are very well marked in the medullary organ. 1st. The spina ventosa in which this organ is distended in a very evident manner with the body of the bone, proves its extensibility. 2d. The contractility of texture is made apparent by the contraction of the cells, after the amputation of the middle part of a long bone, a contraction which prevents the flow of marrow, which without it would take place on account of the communication of these cells.

It is probable that the insensible organic contractility, which is then brought into action by the contact of the air upon this membrane which contracts from its irritation, has an influence also upon this phenomenon; for this membrane evidently has this kind of contractility, as well as the corresponding sensibility.

The animal sensibility is developed in it to an extreme degree in the natural state; the most acute pains are the result of the action of the saw upon it in amputation, of the introduction of a probe, of the injection of an irritating fluid into the medullary cavity, or of any other means which powerfully excite it. I do not speak of the pains of the bones in spina ventosa, syphilis, &c.; as the membrane is not then in a natural state, we cannot infer from

them what kind of vital forces it is naturally endowed with. I have observed that the sensibility is greater, as we approach the centre of the bone with the probe when pushed into living animals. At the extremity of the medullary canal this sensibility is small; in the middle, the division of the bone is very painful. Whence arises this inequality of sensitive power, this decrease from the centre to the extremities? I know not. The medullary system evidently does not possess animal contractility and sensible organic contractility.

It is evident from this view of the vital forces which animate this system, that the life is much more active in it than in the osseous system, that its vital phenomena are consequently more rapid, that they have not that chronic course which characterizes all the diseases of the bones and that they respond more promptly to the sympathetic excitements of other organs. I am persuaded that many of the uncertain pains which we usually refer to the bones in diseases, have their seat rather in the medullary system, in that of the middle of the long bones especially; observe in fact that most of these pains are fixed in the middle of the limbs, and that they are really in the direction of that system. The medullary system of the extremities of the long bones, and of the flat and short ones, certainly enjoys much more vital energy than the osseous texture itself; inflammation is much more easily developed in it, its effects are more promptly shown. Who does not know that caries is so much the more rapid, in proportion to the quantity of the texture of the cells that exists in the bones? It is not this texture, which by its nature, has an influence upon this phenomenon; but it is, because the more abundant it is, the more the medullary system predominates in it; now as this participates in all its affections, it imprints upon them a rapidity which they have not in the compact texture in which it does not exist.

IV. *Development.*

This membrane exists in the cartilaginous state of the middle part of the long bones; but then it serves for the nutritive parenchyma to the gelatine that is exhaled there, and which, accumulated in very great quantity in its cells, renders the bone homogeneous in appearance, and prevents it from being distinguished. When ossification takes place, this substance is absorbed; the medullary cavity is formed; the medullary membrane is bare; the blood enters its vessels, till then permeable only by white fluids, because its kind of organic sensibility changes. Instead of receiving gelatine in its cells, it is the marrow or another fluid that it admits there, a phenomenon also dependant upon this change of organic sensibility. Hence an external form wholly new, a new organ in appearance, whilst in reality it is not the organ which changes, but the fluid that is deposited in it. The same phenomenon nearly is observed in the formation of callus, in which the portion of the medullary membrane corresponding to the fracture is at first cartilaginous, then osseous, and finally becomes what it was originally.

The exhalation of the marrow does not commence when the blood enters the medullary canal, or rather it commences, but I have found that it is wholly different from what it is afterwards in the adult. The proportion of oily substance is almost nothing in it, compared to what we have seen in the medullary fluid. 1st. It has a mucilaginous and reddish appearance; pressed between the fingers, it does not give out an oil as in the adult, but a fluid like gelatine. 2d. By comparing the water in which the marrow of the two ages has been boiled, we cannot see in the first, as in the other, many oily drops floating on the surface. 3d. Exposed to the action of fire, the middle of a long bone lets fall an infinite number of small burning drops, very beautiful, of a blue

tinge and which are furnished by the marrow, which burns after being melted. Nothing similar to this is observed in the fœtus. 4th. We know that the taste of the marrow is very different in young animals, in veal, for example, from what it is in adult ones. It is insipid, disagreeable, little esteemed in the first. 5th. I have observed that the marrow of children soon putrifies, becomes green, then black, if their fresh bones have been kept for some time in the air. The odour of this putrid marrow is very fetid. Preserve, on the contrary, for some time the bones of an adult, you will observe that their marrow turns rancid, and becomes of a deep yellow colour, like all fat that has been some time kept. In general the action of the air is wholly different upon the medullary organ, in the first and in the after ages. What is the fluid which this organ especially separates in the fœtus and in childhood, and which then takes the place of the oily substance? It is an interesting object of research. Do the vulgar, who connect the idea of fat with that of marrow, know this phenomenon, when they say that children have yet no marrow in the bones? This absence of medullary fat in the fœtus, essentially distinguishes the marrow from the ordinary fat, which, at this age, is already very abundant.

Functions.

The first and principal use of the medullary organ is to separate the marrow from the mass of blood by means of exhalation, for it has no glands, and afterwards carry it into it again by absorption, when it has remained for a certain time in its reservoir. This double phenomenon is very analogous to that which takes place in regard to the fat, for which we see that there are two orders of vessels distinct from the sanguineous, that enter its texture; it is not possible however to demonstrate them anatomically.

Is the activity of the exhalants varied by exercise or rest, heat or cold, corpulency or emaciation? We have not any precise experiment upon this subject, though numerous conjectures have been made. But we know that in phthisis, dropsy and marasmus, and in general, in all those states of the body in which general debility is carried to an extreme by the slow and gradual loss of the forces, the marrow, like the other fluids as well as the solids, is changed, loses its essential characters, its consistence and takes an appearance wholly different, without however the medullary membrane experiencing any lesion, or being thickened. I have never observed this lesion except in rickets. The appearance of the marrow in these diseases is mucilaginous, gelatinous, similar to what is seen in the fœtus, with the difference of the redness, which is produced in the first age, by the great number of blood vessels.

The medullary membrane has a direct relation with the nutrition of the bone, a relation which has been proved by the beautiful experiments of Trojat, from which it follows that the destruction of this membrane produces the death of the bone, which has necrosis and is replaced by new bone, for which the periosteum serves for the nutritive parenchyma. These experiments are usually made, by sawing a long bone at its extremity, and introducing into the medullary cavity a red hot probe, which destroys the whole organization. Soon after the periosteum swells, inflames and has an extreme sensibility to the external touch. This sensibility is gradually lessened; the inflammation disappears. A considerable quantity of gelatine penetrates the internal layers of this membrane, which becomes a cartilaginous sac, with which the bone is covered. At the end of some time, which varies according to the class of animals subjected to the experiment, according to their age, their temperament and other causes, the vascular system, destroyed on the

interior of the canal, and expended wholly upon the periosteum, deposits there the phosphate of lime destined for the bone. To the cartilaginous cylinder then succeeds the osseous one. The bone within has no connexion with the life of the living body that surrounds it on all sides. There are then in artificial ossifications three very distinct periods, 1st, swelling and inflammation of the periosteum; 2d, cartilaginous state of the internal layers of this membrane; 3d, osseous state. Besides, these two last states are not as regular and distinct, nor as easy to be observed as in natural ossification.

Does the medullary membrane serve indirectly to furnish a part of the synovia by the transudation of the marrow through the extremity of the long bones? Most authors assert it. We know at the present day, what must be thought of these mechanical transudations, which are observed in dead bodies, but which are repugnant to the known phenomena of vitality; besides, the following experiment leaves no doubt upon this point. I have opened upon the sides two long bones of one of the hind legs of a dog, so as to pass in a red hot probe, which having been carried in several times, completely destroyed the two medullary systems; necrosis has been pretty soon the consequence of this experiment, and yet the articulation between the two bones with necrosis, has continued to receive synovia as usual, a circumstance that would not have happened, if the transudation of the marrow was necessary to the production of this fluid. Who does not know, on the other hand, that in diseases of the articulations in which the synovia is altered and vitiated, the marrow of the corresponding bones is almost always in a perfectly sound state, and that vice versa, in the diseases which attack the medullary organ, the synovia is not altered in its nature like the fluid which this organ contains in its cells?

CARTILAGINOUS SYSTEM.

THE word cartilage is employed too vaguely. It designates, in the common acceptation, bodies whose organization differ essentially. The cartilages of the nose and those of the articular surfaces have certainly but a very remote analogy between them; it is necessary then to establish a line of demarcation. I have endeavoured to do it by making two systems of them; one comprehends the cartilages properly so called, the other, the fibro-cartilaginous substances, such as those that are between the vertebræ, those in the middle of some articulations, &c. As this last is a compound of the fibrous and cartilaginous system, I shall not treat of it until I have spoken of the fibrous system.

By thus limiting the sense of the word cartilage, it gives us the idea of a hard, elastic, white substance, having an inorganic appearance, though it has a real organization. We find this animal substance in different parts of the body; it is met with especially, 1st, at the articular extremities of the moveable bones; 2d, on the articular surfaces of the immoveable bones; 3d, on the parietes of certain cavities, which it contributes in great measure to form; such are the cartilages of the nasal par-

tition, of the ribs, the larynx, &c. Hence three different classes, which exhibit varieties in their forms, in their organization, &c.

ARTICLE FIRST.

OF THE FORMS OF THE CARTILAGINOUS SYSTEM.

The forms of the cartilages vary according to the class to which the cartilage belongs.

I. *Forms of the Cartilages of the Moveable Articulations.*

In every moveable articulation, there is at each osseous extremity, a cartilage which covers this extremity, which facilitates by its suppleness the motion of the two bones, the very hard substance of which would occasion by friction too great a shock; which reflects by its elasticity a considerable part of the motion, thus made more extensive; which breaks, by yielding a little, the violence of the shocks the limbs experience, and which thus render these shocks less dangerous.

The general character of the internal conformation peculiar to these cartilages is that of being always less thick than broad, of having a thickness which is in the ratio of their breadth: so that the cartilages of the great articulations exceed in this respect two, three, or four times even, those of the smaller articulations; and these cartilages are moulded upon the articular forms and exhibit two faces and a circumference.

One of these faces adheres to the bone; it unites with it so intimately, that fractures take place any where else rather than here. The means of union are not exactly known; this is certain, that the cartilage is not an elongation, a continuation of the cartilaginous parenchyma of the bone; the fibres of this parenchyma are not continuous with those of the cartilages. If it really was so, by removing from a long bone, fresh and clothed with its cartilage, the phosphate of lime which penetrates it, we should see this continuity, the bone and the cartilage would not differ; now I have constantly observed that in this experiment the action of the acid detaches the cartilage from the bone, either in fragments or as a whole. We see the cartilaginous fibres of the bone deprived of its saline base, terminating evidently on the convex surface which the cartilage embraces; no solution of continuity has taken place. In general, the appearance of the cartilaginous parenchyma, separate from its calcareous portion, is wholly different from that of a true cartilage. I presume that this difference is owing to the quantity of gelatine, which is greater in the second than in the first. The action of the acids, especially the nitric, is the best means of separating a cartilage from its osseous head; maceration does not produce this phenomenon under a great length of time; in ebullition, as the gelatine melts, it is less apparent.

The surface of the cartilage opposite to the bone, is intimately united to the synovial membrane of the articulation. It borrows from it the polish which it has; for wherever these substances do not correspond to this membrane, they lose this character, as we see in the larynx, in the cartilages of the ribs, &c. Here the means of adhesion is an extremely compact cellular texture, which neither maceration nor dissection can remove in layers. As the synovial membrane is wholly formed from this texture, it appears that upon the cartilage it is

only an elongation of that which, after having contributed to the structure of this organ, is condensed upon its surface and organized as a membrane.

The circumference of the cartilages of which we are treating, terminates insensibly upon the osseous surface; it ceases at the place, where the synovial membrane quits the bone to be reflected.

The two corresponding cartilages of a moveable articulation are so arranged and adapted to each other, that in the medium position of the articulation, they touch exactly at all their points; now we know that the medium position of an articulation is that in which the bone inclines in neither direction, in which all the muscles contracting uniformly and making an equal resistance, keep it equally from extension and flexion, from adduction and abduction, &c. &c. and hold it in the exact medium. It is this position which the limbs take, when the will does not direct the muscular effort, as for example, in the fœtus, in sleep, in rest, &c.; this is what some convulsions produce, in which all the muscles of a limb are agitated with an equal effort, by an extraordinary influx of the nervous power, &c. In no other position does the contact of the two articular cartilages take place at all their points; one portion of the surface of each always pushes with more or less force the parts surrounding the articulation, and distends them. The softness of the cartilaginous texture renders less painful this pressure, which would be distressing in the great motions, if the bones preserved their hardness at the extremity of the lever which they represent.

The cartilaginous forms of which we are treating, besides these common characters, have others peculiar to each kind of moveable articulations.

1st. In the first kind, the convex crust which covers the osseous head, is thick in the centre, but not at the circumference. An opposite arrangement takes place in

the concave crust which receives this head; often even as in the humerus, and the femur, the thickness of this crust is increased at its circumference by a fibro-cartilaginous band. In this way, the effort is borne unequally by the two cartilages; but the uniformity of contact is established.

2d. In the second kind, which differs from the first by the absence of the motion of rotation, though in general a convexity is also received into a concavity, the arrangement for both the cartilages is nearly the same. Yet if two convex surfaces slide upon each other, an example of which we have in the condyle of the jaw and the transverse apophysis, then the cartilage is constantly becoming thinner towards the circumference of each; but then an inter-articular cartilage, thick at the circumference, thin in the middle, supplies the place of this arrangement, and establishes at all points a contact, which, without it, would only take place at the centre.

3d. In the third kind, the cartilaginous crust which covers the prominences and depressions, which reciprocally receive each other upon the extremities of the two bones, exhibits nearly an uniform thickness, as we see at the elbow, the knee, &c.; so that the pressure comes equally upon the whole articular surface.

4th. In the fourth and fifth kinds, the cartilaginous crusts moulded on the form of the osseous surfaces, have also a thickness nearly uniform at all points; I have found upon the bones of an adult, that this thickness is a line and a half in the radio-cubital articulation and that of the atlas, and a line in the carpal and metacarpal articulations.

II. *Forms of the Cartilages of the Immoveable Articulations.*

The cartilages are found only in two kinds of immoveable articulations, viz. in those with surfaces in juxta-

position and those with indented surfaces. They form in all a very thin layer, continued upon both bones which articulate together, arising from their osseous portion, like those described before, being of the same nature as it, and forming a band so much the more close as we advance in age.

On the head these cartilages are very numerous; those of the cranium have more thickness on the convex than on the concave side, hence the more rapid disappearance of sutures in the last than in the first direction.

Wherever they are found, they contribute to unite the bones which form the cavities; hence, as we have said, there is less danger for these from external bodies, since the motion lost then in part in their soft texture, produces a less effect than if the cavity was only one osseous piece.

It appears that these cartilages have much more affinity to the phosphate of lime, than those of the moveable articulations, which rarely ossify, whilst at an advanced age these always become osseous, of which the cranium especially furnishes us examples. I would observe however that the cartilages of the indented surfaces have much more tendency to ossification than those of the surfaces in juxta-position. At least it is more common to see the parietal bones united with the occipital and frontal, than to see the union of the ossa maxillaria, ossa palati, &c.

III. *Forms of the Cartilages of the Cavities.*

The cartilages of the cavities have two different forms according to the parts which they contribute to form. They are, 1st, long, as in the ribs; 2d, flat, as in the larynx, the nasal partition, &c.

All are covered on the exterior with a fibrous membrane like the periosteum, and in which different muscles

are inserted. In order to see this membrane it is necessary to macerate the cartilage for a day or two; it then becomes white and very evident in its thickness, and the direction of its fibres. The cartilages of the cavities do not exhibit the numerous foramina which are seen in the bones, because the blood vessels do not penetrate them. But few eminences and depressions are observed in them. We can hardly consider their forms in a general manner, because destined to very different uses, they have but little resemblance in their conformation.

ARTICLE SECOND.

ORGANIZATION OF THE CARTILAGINOUS SYSTEM.

In examining a cartilage in its interior, it is difficult to recognize in it an organic texture; there is one however, which is composed of a peculiar texture and of common textures.

I. *Texture peculiar to the Cartilaginous System.*

The peculiar cartilaginous texture exhibits an interlacing of fibres so compact, that it appears at first view homogeneous, formed into a mass of gelatine, without order and without any particular direction. Yet with a little attention we distinguish longitudinal fibres, which are crossed by tranverse and oblique ones.

These fibres are more apparent in the cartilages of the moveable osseous extremities than in the others. They

have infinitely less suppleness than the fibres of the fibro-cartilaginous substances; thus these bend without breaking, whilst the first break when they are bent considerably; the place of the rupture is smooth, with but few inequalities.

The cartilaginous texture is remarkable for many characters which distinguish it from the others. Next to the osseous texture, no one so long resists putrefaction and maceration. In the midst of a dead body wholly putrid, we find this texture almost untouched, preserving its appearance, its structure, and even oftentimes its natural whiteness. The same thing is frequently seen in gangrenous limbs in the living body. I have kept cartilaginous substances a very long time in water, which have not become altered, except a little in their colour. It would require more than a year perhaps, to reduce them to that soft, mucous, liquid pulp, to which maceration reduces most of the organs.

The cartilaginous texture contracts under the very powerful action of caloric, like all the other textures; yet this phenomenon is not apparent in the thyroid cartilage on account of its thickness, nor in the cartilages that encrust the bones, on account of their adhesion to these bones. But if we cut one in fine layers, and the others in slices, and plunge them into boiling water, they crisp up immediately and with force.

Exposed to drying, the cartilaginous texture becomes yellow, acquires a semi-transparency analogous to that of the tendons and dried ligaments; it becomes hard, contracts, diminishes in size, and loses its elasticity as it becomes hard.

Ebullition also gives it at first a yellow colour, then it cracks it upon the articular extremities, breaks it in different places, and raises it by layers which it softens, and which finally it melts almost completely to a small residue, which does not appear to be gelatinous. The

softening of the cartilaginous texture renders it much more fit to be dissolved by the digestive juices than it naturally is. Swallowed raw, the cartilages would remain a long time in the stomach, whilst they are very easily digested when cooked; this is one of the very great advantages of the boiling of meat. In different experiments made upon digestion, I have found portions of cartilages still untouched in the stomach of dogs, whilst the flesh was already reduced to a pulp.

In certain cases, the cartilaginous texture is singularly altered. In the diseases of the articulation of the hip, it assumes an aspect wholly different; it is a soft substance, like lard, with very distinct vessels, sometimes with very evident fibres, having a size double, quadruple what is natural, and filling the cotyloid cavity. I have observed that then they do not become yellow, do not melt by ebullition and consequently are not gelatinous. In the same diseases, I have found the cartilaginous texture, upon the femur and the ilium, not only ossified, but changed into a substance exactly like ivory; I have preserved these two pieces.

When the cartilages become osseous, there is developed in their middle a texture analogous to that of the texture of the cells of the bones, in which the interlaced fibres leave between them very distinct spaces, and in which is deposited a kind of medullary fluid. This observation is especially applicable to those of the cavities, of the larynx, of the thorax, &c.

II. *Parts common to the Organization of the Cartilaginous System.*

There is cellular texture in the cartilages, though the want of interstices between their fibres, renders it very difficult to distinguish it in a natural state; in fact the development of fleshy granulations in wounds in which

they are concerned, ebullition which, after having removed the gelatine, leaves a membranous and cellular residue, prove abundantly the existence of this texture, which we see besides in a very evident manner in some morbid states, in which the gelatine less copiously deposited in the cartilages, ceases to give them their usual hardness and leaves there a soft texture, often like sponge.

We do not discover any blood vessels in the cartilages. The exhalant system circulates only white fluids in them; but as this system is continuous with the arteries of the neighbouring parts, when the organic sensibility is raised in it by morbid irritations, and it thus becomes in relation with the red globules of the blood, these globules easily pass into it, and hence the redness the cartilages then have, as we see in their inflammation, in wounds of them, &c. It is this same phenomenon that we observe upon an inflamed conjunctiva, &c. When the irritating cause has ceased, the sensibility resumes its natural type, the red globules then become heterogeneous to the cartilage, which again becomes white.

We are ignorant of the nature of the white fluids which usually circulate in the vascular system of the cartilages. These fluids very easily become the vehicle of the bile, or at least of its colouring matter, which is spread through the animal economy in jaundice. We observe almost uniformly, that in this disease the cartilages are of a yellow colour, like all the other parts; the colour is more evident on their surface than in their texture, though it exists there. By opening a moveable articulation, the bilious appearance is commonly found as great there as upon the skin. Besides, all the parts, which like them, receive but few or no red globules in the ordinary state, are also found very evidently coloured. The tendons, the conjunctiva, the internal membrane of the arteries, &c. are examples of this. I have remarked in two subjects whose thyroid cartilages were ossified in the middle, that

the yellow colour was much brighter in the osseous than in the cartilaginous portion. I do not know that nerves have ever been traced in the cartilages.

ARTICLE THIRD.

PROPERTIES OF THE CARTILAGINOUS SYSTEM.

I. *Physical Properties.*

Elasticity is a property generally extended to all organic and inorganic bodies. Among the first, it appears, that vegetables are endowed with it in the greater number of their organs; that animals, almost all of whose parts are soft, have some which return to their original state after having been stretched or compressed. Among these, the cartilages hold one of the first ranks in man. Their elasticity is very great, especially in the adult age, when their consistence is between the softness, which characterizes them in childhood, and the hardness, which is their attendant in old age. These two last properties are in fact not favourable to the elastic power.

If we plunge a scalpel into a cartilage, the edges of the divided place re-act upon it and expel it. Pressed against a resisting body, the cartilaginous extremity of a long bone becomes flat and resumes its form when the compression ceases. The edges of the thyroid cartilage, when it is cut longitudinally in the operation of bronchotomy, immediately approximate each other. The division of the cricoid ring exhibits the same phenomenon. The cartilages of the last ribs, when forced in towards the ab-

domen, come out of themselves, &c. &c. All these phenomena are the evident result of an elastic power. Thus nature has placed the cartilages wherever, to produce her phenomena, there is a necessity of uniting a physical to the vital forces, as in the larynx, in the nasal septum, in order to produce a sort of vibration in the passage of the air, at the extremity of the ribs, in order to be the seat of a species of twisting necessary to the mechanical part of respiration, at the articular extremities, in order to diminish the force of blows, &c.

It appears that the vital activity renders this property greater, which however remains very apparent after death. I presume that this is owing to the great quantity of gelatine they contain. 1st. We know that this substance possesses it in a very high degree, as is proved by the tremulous motion of jelly after it has become cold, by the examination of various animal glues, &c. 2d. If by ebullition we remove this substance from the cartilages, the nutritive parenchyma remains flaccid and soft. 3d. As the gelatine diminishes in our organs, the elasticity in them is less, as we see by examining the decrease of this property from the cartilages in which it predominates, to the fibro-cartilaginous organs in which it is in a smaller proportion, and to the fibrous bodies in which it is still less. It must be confessed however that many very gelatinous bodies, exhibit but very slight traces of elasticity; the skin is an example of this, and so are the tendons. Can the same substance, as it is differently operated upon by the organic laws, become the seat of properties wholly dissimilar?

II. *Properties of Texture.*

The cartilages are perhaps of all the organs, those in which the extensibility and contractility of texture are the least developed. We see them rarely distended and

elongated; they break first. Diseases do not exhibit in the larynx those dilations so common in the other cavities, even the osseous ones. When divided, the edges, far from separating as in the skin, in a muscle, &c. approximate each other, as we have seen, by the effect of elasticity; we might say that this last property was accumulated in the cartilages at the expense of those of texture.

III. *Vital Properties.*

The vital properties are also very obscure in them. There is no animal sensibility in the natural state; it is only when inflammation or some other cause raises their organic sensibility, a sensibility which their functions necessarily suppose, it is only then, I say, that the brain perceives painfully the different irritations of which these organs are the seat. This becomes manifest, especially when foreign bodies are formed in the articulations, which suffer from their presence or are insensible to them, according as they irritate or not by their position, the cartilaginous extremities. There is neither animal nor sensible organic contractility in the cartilages; the insensible organic or tone alone exists in them, and this not in a great degree.

The sympathies are obscure, almost wanting in the cartilaginous system. I do not know that in the acute affections of the different organs, we observe sympathetic phenomena of sensibility or contractility in them. They remain tranquil in the midst of the general derangement which affects the other systems in this sort of diseases. In chronic affections even, they experience but little alteration; examine, for example, comparatively, the body of a man that has died a violent death, which has left his organs untouched, and that of one who has died from phthisis, dropsy, cancer, &c. you will perceive between

almost all their organs a striking difference; the aspect of the muscles, of the mucous and serous surfaces, of the vessels, the nerves, &c. is entirely changed by the slow alteration they have undergone in the second; in the midst of these alterations the cartilages are unchanged, their appearance is almost the same as in a natural state.

Character of the Vital Properties.

From what has been said, it is evident that the cartilaginous life can have but little activity, that all the morbid phenomena must be characterized in these organs by a peculiar slowness, and that inflammation, for example, must always have in the cartilages, as in the bones, a chronic progress; this is rendered very clear by the following experiment. Lay bare a cartilage, divide it, and afterwards bring it in contact with a portion of a muscle, the skin, &c. also divided at their surface; the reunion does not take place, or at least not until a very long time. Why? because the life of the muscle or the skin being much more active than that of the cartilages, the inflammation of the first organs will be much more rapid than that of the second, and consequently the first inflammatory period of one will correspond to the last of the others. Now the reunion is so much the easier as the inflammatory periods correspond the more exactly in the two divided parts that are in contact. Hence why two parts of the same organ unite much more easily than two surfaces belonging to different organs. Hence why the greater the analogy in the lives of the two organs, the greater the facility with which they unite; why the difficulties increase as the differences of life become greater. Two osseous surfaces in contact require thirty or forty days to unite; the two edges of a cutaneous wound unite in two or three days. If you attempt to render continuous two organs thus unlike in their mode of cicatrization, by putting them in contact, you will succeed but slowly.

Cover with skin the osseous extremity of an amputated stump; this will be in a state of suppuration, before the bone has hardly begun to soften; thus good practitioners have abandoned these pretended unions by the first intention, so much boasted of, after amputation by the flap operation. These unions would no doubt take place, if the life of the organs which enter into the composition of the flap was the same. But with the diversity of these muscular, osseous, tendinous, cellular, nervous organs, &c. it requires a long time for all their lives to be placed as it were in equilibrium, and for these organs to agglutinate at their divided extremities. I have already observed that the division of inflammations into acute and chronic gives physicians an inexact idea; for the duration of the inflammatory phenomena in the organs is wholly relative to their degree of life. An inflammation of the cellular texture and of the skin is acute, when it lasts but a few days; it is chronic when it continues forty or fifty days; in a cartilage, this last period may be that of an acute inflammation, whilst a duration of many months is necessary to make it chronic, as the diseases of the joints exhibit frequent examples.

The natural functions, as well as the morbid affections, have this slowness of the vital phenomena of the cartilages. The constant composition and decomposition, which their nutrition supposes, is not rapid. It requires a long time for nutritive substances to combine with them. I am persuaded that in animals which die suddenly from the effects of a carbuncle and whose muscles, glands, membranes, &c. almost instantly penetrated with the deleterious principles by the nutritive motion of composition, present an aliment so injurious, I am persuaded, I say, that these injurious principles not yet having penetrated the cartilages, these might be digested without danger. It is to the slowness of the motion of decomposition that must be attributed the slowness of the resolu-

tion of cartilaginous swellings; for tumours are resolved by the same laws that decompose our organs, as they are formed by the same laws that preside over their composition.

The cartilages and the analogous organs, are to the other parts of the economy, as it respects their vitality, what the zoophytes and other animals with a capillary circulation only, are to the animals better organized, to those with a general circulation and those that have a heart with a double ventricle. As much as life considered in general in the series of beings that it animates, presents a difference in its activity, so much it differs in the same respect, examined in particular in the organs of each of these beings.

ARTICLE FOURTH.

DEVELOPMENT OF THE CARTILAGINOUS SYSTEM.

The osseous and cartilaginous systems are confounded in the embryo; as the first is developed, the second contracts; the latter very evidently has gelatine for its principal base; I shall not return to the proofs that have demonstrated it in the osseous system.

I have shown, in speaking of that system, how the cellular and vascular parenchyma, existing at first alone and constituting the mucous state, is penetrated afterwards with this base, which forms the cartilage. The primitive mode of the formation of these organs is then already known. Let us see how its development continues.

I. *State of the Cartilaginous System in the first age.*

As ossification advances in the bones and gelatine is consequently carried to them in less quantity, it seems that it goes more abundantly to the articular surfaces; for the cartilages that are met with, then lose their primitive softness, and have a consistence that is constantly increasing. Yet much more gelatine leaves the bones, than is carried to the cartilages; so that we may say that this substance is continually diminishing, in the organs, in proportion as we advance in age. We know that it is the parts of young animals particularly, that are selected to make glue, jelly, &c. The articular cartilages at this period exhibit a phenomenon that I have frequently noticed in my experiments; when we macerate them in water for two or three days, they take a very evident red colour. This colour does not penetrate deeply; but if we cut the cartilage in many places so as to bring the fluid in contact with its interior, the whole of it becomes red. The cartilages of ossification exhibit the same phenomenon, which becomes less conspicuous as we advance in age; so that in adults generally, the cartilages do not lose their white colour by maceration. In some however they take a reddish tinge which is infinitely less bright than in the fœtus. Whence arises this phenomenon? Does the water give to the cartilage the cause of its colour, or does it take from it by solution certain substances which prevented this colour from being developed? Whatever may be the cause, none of the organs of articulation redden in this way; all on the contrary, the synovial, the ligaments, &c. become whiter.

There is usually no sensible demarcation between the cartilage that is to become bone, and that which is to remain as it is; sometimes however on the one hand we observe a more dull colour at the extremity of the bones,

whilst on the other, we never discover the reddish streaks, which are so frequently seen irregularly scattered on the cartilages of ossification.

As long as ossification continues, there is between the cartilage and the osseous portion already formed, a very evident vascular layer, and it is extremely easy to separate these two portions, which adhere but slightly to each other. We observe also on the surface of each when they are separated, several inequalities, projections and depressions reciprocally adapted to each other. It is the want of adhesion of the cartilaginous and osseous portions, before complete ossification, which has no doubt given rise to all that has been written upon the separation of the epiphyses, a separation which the observations of modern surgeons have rarely confirmed.

As the calcareous substance arrives at the extremities of the bone, the vessels gradually disappear, and the adhesions increase. Finally, the ossification being finished, there is no longer, on the one hand, an evident vascular net-work between the cartilage and the bone; and on the other, their union is such, that all rupture between them is almost impossible. These two characters especially distinguish the relation of the cartilage of ossification with the bone, from that of the real cartilage with the same bone. I have observed also that almost always above its union with the osseous portion, the cartilage of ossification has less whiteness, a deeper tinge, which extends the distance of two or three lines, and whose difference is often very considerable; this is the forerunner of the access of the blood. This arrangement does not exist in the cartilage of the bones of the adult.

We attribute commonly to the articular motions, the want of ossification of the cartilages of the moveable articulations; but I believe that it depends wholly upon the laws of osseous nutrition. Nature limits there the exhalation of the phosphate of lime, as it limits at the

origin of a tendon the exhalation of the fibrin of the muscle which corresponds to it; it is because the mode of organic sensibility changes and the vessels of the cartilages are no longer in relation with the red part of the blood nor with the calcareous substance. In fact, by supposing the preceding hypothesis true, why do the cartilages of the immoveable articulations exist? Why should the motion which elsewhere favours exhalations and secretions, prevent here the first of these? Why do preternatural ossifications take place in the most moveable parts, of which the arteries furnish us an example? Why, in many anchyloses in which the articular surfaces unite, and in which the motion is destroyed, do not the cartilages disappear?

The cartilages of the cavities have a mode of origin, development and nutrition, perfectly analogous to that of the articular cartilages. I would observe that their texture differs, as well as the texture of these, from that of the cartilages of ossification, in this, that these last are crossed by many grey lines, and the others are not. When we cut the cartilages of ossification in any direction whatever, their divided surfaces exhibit numerous small points which are the cut extremities of these lines, which appear to be vessels, that, without yet circulating blood, contain a fluid of a deeper colour than that of the cartilaginous texture.

II. *State of the Cartilaginous System in the after ages.*

As we advance in age, the cartilages become harder, stronger, and less elastic. The gelatine that nourishes them has a peculiar character; for we know that the glue made from young animals differs essentially from that made from old ones. The cooks know very well the difference there is between the foot of a calf and that of an ox

for jelly. This difference in the substance which essentially composes the cartilages, and which is undoubtedly their nutritive matter, evidently indicates that it does not always remain in these organs, but that it is constantly exhaled and absorbed there, as the phosphate of lime is in the bones, the fibrin in the muscles, &c.

In the last years of life, ossification seizes upon all the cartilages; but it begins in an opposite manner in those of the cavities and in those of the articulations. In the first it is by the centre, in the second it is by their surface which corresponds to the bone, that it commences; in general it is much slower in the latter, and among these, it is slower in the moveable articulations than in the immoveable.

The cartilages of the larynx and the ribs are osseous in their centre at the age of thirty-six or forty years, and even before; they afterwards become more and more so; it is this that renders the section of the thyroid cartilage very difficult in the last periods of life.

In the great number of operations that I have shown to students, I have satisfied myself, that after sixty years, the bistoury of ordinary temper is almost always insufficient to make this section; it requires something much stronger. It is the ossification of the costal cartilages, which renders old people unable to make those great efforts of inspiration so common to young ones; with them the diaphragm especially acts. I attribute also to this early ossification of the cartilages of the cavities, an ossification which always accompanies the development of the vascular system, the greater frequency of caries in this sort of cartilages than in all the others. I know not why in the larynx the arytenoid cartilages are the most exposed to this affection; but in the opening of dead bodies, it is a constant fact, all the cases of laryngeal phthisis with caries, that I have observed in the dead body, have shown me this.

III. *Preternatural Development of the Cartilaginous System.*

The cartilaginous system, like the osseous, is often developed in organs to which it is naturally a stranger. But there is this difference, that this phenomenon appears to be an effect of age in the first, whereas in the second it is always the effect of disease. Nothing is more common than to find cartilaginous balls in scirrhous, cancerous tumours, &c.; in the middle of those frequent morbid productions, in which the parts have an appearance like lard, in the lungs, liver, &c. when enlarged. I do not know why the peculiar membrane of the spleen has a great tendency to be encrusted with gelatine; it is perhaps of all the organs, that in which the preternatural cartilages are the most frequent. It is usually by irregular scales that the cartilaginous development appears; sometimes it attacks the whole membrane, which then presents a convex surface analogous to the convex surfaces of the moveable articulations, which the peritoneum covers, as these are covered by the synovial membrane. Can the spleen, when thus cartilaginous externally, yield to the changes of size that it often undergoes? I know not.

We know that there are often moveable and loose cartilaginous substances in the articulations. Do they arise from the ossification of a portion of the synovial membrane? I presume they do; for we frequently see them hold to the cartilage by membranous expansions. I have seen in a dead body, within the last year, the portion of synovial membrane that goes from the fatty substance behind the patella, to the depression that separates the condyles of the femur, almost wholly cartilaginous. If during life it had been detached by the effect of the motions, it would have formed one of these moveable and loose cartilages. Besides, as I know but this fact which seems peculiarly applicable to this point, I can only offer

conjectures, especially as we know that the synovial and serous membranes are of the same nature, and yet these last hardly ever become cartilaginous.

Moreover these productions follow entirely the ordinary progress of ossification. At first cartilaginous and without blood vessels, they soon acquire a red centre, then osseous, which extends from the centre to the circumference, and which sometimes terminates by seizing upon the whole cartilage ; so that they are real bones. This last circumstance is however very rare. The state in which we most commonly find these productions, is that in which they are osseous in the middle, and cartilaginous at the circumference. I found one of them in the articulation of the pisiform bone, of the size of the head of a great pin, and which, in its whole thickness was harder than ivory.

FIBROUS SYSTEM.

THE fibrous organs have not been considered by anatomists in a general manner; no one has yet made a system of them. Separately described with the parts in which they are found, they cannot, in the present state of science, present us any of those great views, so useful to the practice of medicine, which show us each organic apparatus resulting from the combination of different systems, to which analogous ones are found in the other apparatus; so that though very different as it respects their functions, these apparatus are yet subject to the same diseases, because similar systems enter into their structure.

I presented, two years since, various general views upon the fibrous membranes, which have opened the way; but these membranes are only a division of the fibrous system, which must be considered here more at length.

ARTICLE FIRST.

OF THE FORMS AND DIVISIONS OF THE FIBROUS SYSTEM.

Though all the fibrous organs have precisely the same nature, and though the same fibre enters into the compo-

sition of all, yet the forms which they assume are extremely various; it is this variety of form, joined to that of their position and their functions, which has given them a different denomination, and made us designate them by the name of tendons, aponeuroses, ligaments, &c.; for there is no general denomination for the whole system, no word which answers for example to that of muscle, nerve, &c. which in the muscular, nervous systems, &c. gives an idea of the organization, whatever may be the form of the organ. I shall not create a word, I shall be easily understood without it.

All the fibrous forms can be referred to two general ones; one of these is membranous, the other in fasciæ. The organ is broad and thin in the first; it is longer and thicker in the second. Thus the muscles, the nerves, the bones themselves exhibit alternately this arrangement in their conformation, as we see in the retina compared with the round nerves, in the muscular layers of the stomach and the intestines, compared with the muscles of locomotion, and in the bones of the cranium compared with those of the extremities.

I. *Of the Fibrous Organs of a Membranous Form.*

The fibrous organs arranged as membranes are, 1st, the fibrous membranes, properly so called; 2d, the fibrous capsules; 3d, the tendinous sheaths; 4th, the aponeuroses.

1st. The fibrous membranes comprehend the periosteum, the dura-mater, the sclerotica, the albuginea, the peculiar membranes of the kidney, the spleen, &c. &c. They are in general destined to form the covering of certain organs, into the structure of which they enter.

2d. The fibrous capsules, very distinct, as we shall see, from the synovial surfaces, are a kind of cylindrical sacs, which are found around certain articulations, especially those of the humerus and the femur, whose connexions

with the scapula and the ilium they strengthen, by embracing with their two extremities, both surfaces of the articulation.

3d. The fibrous sheaths are destined to confine the tendons in their passage upon the bones, where they are reflected, and generally wherever by muscular contraction they would be made to deviate and consequently transmit with difficulty to the bones the motion they receive from the muscles. They may be divided into two kinds; one receives and transmits the tendons of many muscles united, as is seen at the wrist, the instep, &c.; the other, like that of the fingers, is destined for a single tendon, or two only.

4th. The aponeuroses are a kind of fibrous nets more or less broad, entering always into the system of locomotion, and so arranged that they sometimes form coverings for different parts, and sometimes furnish the muscles with points of insertion. Hence the aponeuroses of covering and the aponeuroses of insertion; each of them is divided into species.

The aponeuroses of covering are placed sometimes around a muscle, to which they serve as a general sheath, as we see on the thigh, the fore-arm, &c.; sometimes upon certain muscles which they partially retain in their respective places, as that which goes from the posterior and superior serratus minor to the anterior and inferior, as the abdominal aponeurosis, as that situated anteriorly to the solæus, behind the deep muscles of the leg, &c.

The aponeuroses of insertion are sometimes with surfaces more or less broad, as in the attachments of the triceps femoris, the rectus, the biceps, &c.; sometimes with fibres separate from each other, and giving attachment by each of these fibres to a fleshy fibre, as at the superior insertion of the iliacus, of the anterior tibialis, &c.; sometimes finally in the form of an arch, and then at the same time that they give the muscles points of in-

sertion, they allow vessels to pass under them, as in the diaphragm, the solæus, &c.

II. *Of the Fibrous Organs in the form of Fasciæ.*

The fibrous organs arranged in fasciæ are, 1st, the tendons; 2d, the ligaments.

1st. The tendons are found at the origin, insertion or middle of the muscles. They are either simple, in the form of elongated cords, as in the peronæus, the tibialis, and almost all the muscles, or compound, as in the rectus, the flexors, &c.

2d. The ligaments strengthen the osseous or cartilaginous articulations, around which they are found. They have regular fasciæ, as the lateral ligaments of the elbow, the knee, the jaw, &c.; or irregular fasciæ, as those of the pelvis.

III. *Table of the Fibrous System.*

We can in the following table present at a single view the classification of the fibrous organs that I have just pointed out.

FIBROUS ORGANS.

- Of a membranous form.
  - Fibrous Membranes.
  - Fibrous Capsules.
  - Fibrous Sheaths.
    - Partial.
    - General.
  - Aponeuroses
    - For covering
      - Partial.
      - General.
    - Of Insertion
      - With a broad surface.
      - In an arch.
      - With separate fibres.
- In the form of fasciæ.
  - Tendons
    - Simple.
    - Compound.
  - Ligaments
    - With regular fasciæ.
    - With irregular fasciæ.

Though the numerous organs which enter into this classification, belong to very different apparatus, though they seem to be spread here and there in the economy,

without holding together at all, and though all appear insulated, yet they are almost all continuous and connected; so that we may consider the fibrous system, like the vascular and cerebral nervous systems, that is to say, as having a common centre, from which all the different organs go that form its divisions.

This common centre of the fibrous system appears to me to be the periosteum, not that I pretend that like the heart or the brain, it sends out radiations upon the organs that go from it, but because anatomical inspection shows us that all the fibrous organs are intimately connected with it, and by its means communicate with each other; the following observations are a proof of this.

1st. Among the fibrous membranes, that of the corpus cavernosum intermixes with the periosteum below the ischium; the dura-mater is continued with it through the foramina at the base of the brain; by uniting itself by the lamina which accompanies the optic nerve to the sclerotica, it joins to it this membrane, and thus serves as an intermediate organ for them. 2d. All the fibrous capsules above and below the articulation intermix with the periosteum. 3d. Wherever fibrous sheaths exist their fibres intermix with those of the periosteum. 4th. All the aponeuroses either of covering or insertion have a similar intermixing. 5th. Wherever the tendons are expanded, they are also confounded with this membrane. 6th. At the two extremities of the ligaments it unites also its fibres to theirs. There are none scarcely except the albuginea, the perichondrium of the larynx, the membranes of the spleen and the kidney, that form an exception to this general rule.

The fibrous system should be considered then in a general manner, that is to say, as extending itself everywhere, belonging at the same time to many organic apparatus, distinct in each by its form, but continuous in the greatest number, having everywhere communications.

This manner of describing it will appear still more natural, if we consider that the periosteum, the general boundary of the different portions of this system, is itself everywhere continuous, and at the place where the articulations divide it, the fibrous capsules and the ligaments serve, as we have said, to reunite it.

We understand from this use of the periosteum in relation to the fibrous system, what the advantage is of its situation upon the bones which offer it a solid support, and give the same also to the organs of which it is the boundary.

ARTICLE SECOND.

ORGANIZATION OF THE FIBROUS SYSTEM.

In the midst of the varieties of form that we have just examined, the general organization of the fibrous organs is always nearly the same. I shall now consider this organization; I shall treat elsewhere of the varieties it experiences in each part. It arises from the union of a peculiar texture and of the vascular, cellular systems, &c.

I. *Of the Texture peculiar to the Organization of the Fibrous System.*

Every fibrous organ has for a base a fibre of a peculiar nature, hard, but slightly elastic, insensible, scarcely at all contractile, sometimes in juxta-position and parallel to each other, as in the tendons and the ligaments, some-

times crossed in various directions, as in the membranes, the capsules, the fibrous sheaths, &c. but everywhere the same, everywhere of a white or greyish colour, and of a remarkable resistance.

This resistance of the fibrous texture enables all the organs that it composes to support the greatest efforts. Thus these organs are all destined to uses which require this faculty in them. The ligaments forcibly retain the articular surfaces in their proper relation. The aponeuroses confine the muscles and oppose their displacement. The tendons constantly exposed to the contraction of these organs, are at every instant placed between the strong power that they represent and the more or less considerable resistance situated at the extremity of the muscles, &c. Such is this resistance, that it is often greater than that of the bones themselves. We know that by muscular efforts alone, the patella, the olecranon process and the os calcis are sometimes broken ; now this could not happen, if the extensor tendons, which corres ponded to these different bones, were of a texture tha could be more easily torn.

It is to this resistance that must be attributed the following phenomena : 1st. We experience the greatest difficulties in making luxations in the dead body, principally in the articulations called enarthrodial. 2d. In the living subject the external efforts are rarely sufficient to produce them ; it is necessary that the powerful action of the muscles should be added. 3d. The punishment formerly employed, of drawing the limbs of criminals by attaching horses to them, was much more terrible, because the resistance of the ligaments made it continue longer ; almost always the horses were unable to produce the separation of the extremities ; it was necessary that a cutting instrument should assist their efforts. 4th. Weights suspended to a tendon do not break it unless they are enormous ; thus the best strings to be employed in the arts would be

these textures of the fibrous organs, if drying did not take from these organs their softness and flexibility, if moisture did not alter them, &c. 5th. We cannot without great efforts tear an aponeurosis, especially those of any thickness, as the fascia lata, the albuginea, the dura-mater, &c.

Yet this resistance is sometimes overcome in the living body, and we sometimes see the rupture of the tendons of the solæus, of the small plantaris, of the extensors of the thigh, &c. How does it happen, that the softer texture of the muscle never yields, whilst that of the tendon much more compact is broken? It is because in these cases the fleshy fibres are always in contraction; consequently far from being stretched, as the tendinous fibres are which are then found, if we may so say, passive, their different portions make an effort to approximate each other; and they do in fact approximate; this gives to the muscle a density and hardness equal, and in some cases even much greater, than those of their tendon, as we can ascertain by applying the hand upon a muscle in contraction. A proof that this kind of ruptures is owing to the cause I have mentioned, is this, that if in a dead body we suspend a weight to a muscle detached from the bone at one of its extremities, it will be the fleshy and not the tendinous portion that will break.

The fibrous texture has been considered by some anatomists, as being of a nature approaching that of the muscular texture, and even as being sometimes the continuation of it. Thus they have said that the tendon was formed only by an approximation of the fleshy fibres, which, without changing their nature, only lose their redness. Thus the aponeuroses of covering have been described as an effect of the pressure of the surrounding bodies upon the most external fleshy fibres. In order to see how little foundation there is for this opinion, it is sufficient to observe, 1st, that the dura-mater, the scle-

rotica, the periosteum, the ligaments, are evidently of the same nature as the tendons and the aponeuroses, and that yet they differ wholly from the muscular texture ; 2d, that the chemical composition, the vital properties, the apparent texture, are entirely different in the tendinous and muscular fibre ; 3d, that there is no relation between their functions. There is certainly less analogy between the muscle and the tendon which receives its insertion, than between that and the bone which furnishes an attachment to it, and whose cartilaginous portion approximates it in its nature. A muscle and its tendon form an organic apparatus and not a simple organ.

What is the nature of the fibrous texture? We know not, because we do not know any of its properties that are characteristic ; it has only the negative ones of those of the muscular texture which is distinguished by contractility, and of those of the nervous texture which is characterized by sensibility. We always see it in a passive state ; it obeys the action that is imparted to it, and has scarcely any of its own.

It establishes a great difference between the organs in which it exists and the skin, the cellular texture, the cartilages, the serous membranes, &c. ; thus it was wrong to refer all these parts to one and the same class designated by the name of the white organs, a vague term that is only founded upon external appearances, upon the approximation of analyses yet incomplete, and not upon the texture, the vital properties, the life and the functions of the organs. Fourcroy foresaw that this extremely general division would be abandoned after further experiments.

However this may be, the following are the results which the fibrous texture gives when subjected to maceration, ebullition, drying, the action of the acids, &c.

Exposed to maceration in a moderate temperature, the fibrous texture remains a long time without undergoing

any alteration; it preserves its size, form and density; gradually this last diminishes; the texture softens; but it does not dilate and swell up; its fibres can then be separated from each other; we see distinctly between them the cellular texture that unites them. Finally at the end of a very long time, they become changed into a soft, whitish pulp, which appears to be homogeneous. All the fibrous organs do not soften equally quick in this way. The tendons are the first to yield to maceration. Then come the aponeuroses; among these, those which are formed by the expansion of a tendon, soften quicker than those destined to cover the limbs, as the fascia lata, for example. The fibrous membranes, the capsules and the sheaths of the same nature are more resisting. Finally the ligaments yield the slowest to the action of water which tends to soften them; yet when they come originally from a tendon, as the inferior ligament of the patella, they are more easily macerated. I have made comparatively, experiments upon all these organs; they give the results that I have stated.

Every fibrous organ plunged into boiling water, or exposed to great heat, crisps and contracts like most of the other animal textures; it diminishes in size, hence it is more solid; it becomes elastic which it is not in the natural state, and afterwards it ceases to be so when it becomes softer before passing into the gelatinous state. By placing all the parts of this system at the same time in water which is made gradually to boil, we see that this softening comes upon all at the same degree, and with nearly the same force. This force, which tends then to make the fibres of this system contract is very considerable; it is sufficient to break at the place of their attachments, those of the periosteum which it raises, by this mechanism, from all the bones that have been boiled for a length of time; to detach the interosseous ligaments, the obturator membrane, &c. when we plunge

them into boiling water, with the bones to which they adhere; to contract so strongly the articular surfaces against each other, that they cannot be moved, when, surrounded with their ligaments, they have been exposed to the concentrated action of caloric.

The fibrous texture gradually softens in water, becomes yellowish, semi-transparent and finally melts in part. By boiling together all the parts of the fibrous system, I have observed that the tendons soften first, then the aponeuroses, then the membranes, fibrous capsules and sheaths, and finally the ligaments, which are, as in maceration, those that yield last. Many have already made this remark, to which I add that all do not yield equally. Those placed between the layers of the vertebræ are the most tenacious; they do not take that yellow colour, that semi-transparency, common to all the fibrous system when boiled; they remain white and tough; they appear to contain much less gelatine, and to be entirely different in their nature.

Exposed to the action of the air, the fibrous system loses its whiteness by the evaporation of the fluids it contains; it acquires the horny hardening, becomes yellow, in part transparent and breaks with facility. Some days after having been dried, if replunged into water, it becomes nearly as white and soft as it was before; so that we can truly say, that its white colour is owing to water alone; this phenomenon takes place especially in the tendons. I have observed also in these last another remarkable phenomenon; it is that when they have macerated for some time, and are afterwards dried, they do not become yellow in drying, but remain of a very decided white. Without doubt the whole fibrous system would do the same.

The action of sulphuric and nitric acids quickly softens the fibrous texture, and reduces it to a kind of pulp, blackish in one and yellowish in the other; at the instant

we plunge this texture into the acid, it crisps and contracts as in boiling water.

The fibrous texture resists in general putrefaction less than the cartilaginous; but it yields to it more slowly than the medullary, the cutaneous, the mucous, &c. In the midst of these putrid and disorganized textures in the subjects in our dissecting rooms, we find this still untouched; it finally becomes changed also. Water in which it has been macerated gives an odour less offensive than that which has been used for the maceration of most of the other systems.

More digestible than the cartilages and the fibro-cartilages, the fibrous texture is less so than most of the others. The experiments of Spallanzani and Gosse prove this. It appears that it yields to the action of the digestive juices in the same order as to maceration, ebullition, &c.; that is, 1st, the tendons; 2d, the aponeuroses; 3d, the different fibrous membranes; 4th, the ligaments, which are the most indigestible. I would observe however that when boiling has once softened the fibrous texture, it is all digested nearly alike. Thus the cartilages are as easy, and even more so, of digestion, than the tendons, when they have become gelatinous, as Spallanzani proved upon himself, though when raw they are much more indigestible.

II. *Of the Common Parts which enter into the Organization of the Fibrous System.*

The cellular texture exists in all the fibrous organs; but it is more or less abundant according as the fibres are more or less distant. In certain ligaments, it forms for the fibrous fasciæ, sheaths analogous to those of the muscles; in others, in the tendons, the aponeuroses, &c. we hardly perceive it; but everywhere it becomes very evident by maceration, by morbid affections, as, for ex-

ample, by the fungi of the dura-mater by the carcinoma of the testicle, which has seized the albuginea, by certain swellings of the periosteum, &c. In all these cases the fibrous texture relaxed, softened, preternatural, and of a spongy nature permits its fibres to separate and the cellular organ to appear. The development of fleshy granulations, the soft nature which these granulations have in certain wounds in which the fibrous organ is concerned, prove also the existence of the cellular organ there, which is in general in small quantity ; this does not contribute a little to produce the resistance and the force of the organs that belong to it. Does this cellular texture contain fat? At first view we can hardly observe it, since we can scarcely distinguish this texture. Yet I have many times observed that by submitting to desiccation portions of aponeuroses, periosteum, dura-mater, &c. entirely stripped of every foreign part, when all these fluids had evaporated, and the organ had the appearance of parchment, a fatty exudation remaining on many places on its surface.

The existence of vessels varies in the fibrous system ; much developed in some organs, as in the dura-mater, the periosteum, &c. they are less so in others, as the aponeuroses, and not at all in some, as the tendons. I would observe in general that it is in those in which they are the most evident, that inflammations and the different kinds of tumours are the most frequently observed. The affections of the dura-mater, the periosteum, &c. compared with those of the tendons, are a remarkable proof of this.

I do not know that absorbent vessels have been traced in the fibrous system.

The nerves appear to be equally foreign to it, notwithstanding what has been written on those of the periosteum, the dura-mater, &c. &c.

ARTICLE THIRD.

PROPERTIES OF THE FIBROUS SYSTEM.

I. *Physical Properties.*

The fibrous system has but a slight degree of elasticity in the natural state; but when its different organs are taken from the body and dried, they acquire it very considerably; thus the tendons, the aponeurotic expansions, &c. which in a fresh state would be incapable of any vibration, are found to resound in instruments when they are very dry.

II. *Properties of Texture.*

The properties of texture are evident in the fibrous system, but they are less so than in many others.

Extensibility is seen in the dura-mater, in hydrocephalus, in the periosteum; in the different enlargements of which the bones are susceptible; in the aponeuroses, in the swelling of the extremities, and the distension of the abdominal parietes, which, as we know, are aponeurotic as well as fleshy; in the fibrous capsules, in articular dropsies; in the tunica sclerotica and albuginea in the swelling of their respective organs.

This extensibility of the fibrous system is subjected to an uniform law, which is unknown to the extensibility of most of the other systems; it can only take place in a slow, gradual and insensible manner. Thus when it is too quickly put into action, two different phenomena take place, which equally suppose the impossibility of its extending suddenly, as for example, a muscle, the skin, the cellular texture, &c. do. 1st. If the fibrous organ

makes a resistance greater than the effort which it experiences, then it does not yield, and different accidents result from it. We have many examples of this, in the inflammatory swellings that appear under the aponeuroses of the limbs, under those of the cranium, within the fibrous sheaths of the tendons, &c. Then these fibrous organs not being able to stretch with the same rapidity as the subjacent parts which swell, compress painfully these swollen parts, and sometimes even expose them to gangrene; this is what takes place in those strangulations so frequent in surgical practice, and which require different operations to relieve them. 2d. If the fibrous organ is inferior in its resistance to the sudden effort which it experiences, it breaks instead of yielding; hence the rupture of the tendons, the tearing of the fibrous capsules and of the ligaments in luxations, that of the aponeuroses in certain very rare cases reported by different authors, &c. &c. We easily understand that the great resistance with which the fibrous texture is endowed, is principally owing to the impossibility of yielding suddenly to the impulse that is given to it.

In the slow and gradual extension of the fibrous organs, we observe that often instead of becoming thinner and enlarging at the expense of their thickness, they increase, on the contrary, in this dimension. The albuginea of a scirrhous testicle, the sclerotica of a dropsical or cancerous eye, the periosteum of a ricketty bone, &c. show us this phenomenon, the reverse of which is sometimes observed, as in the distensions of the abdominal aponeuroses produced by pregnancy, by ascites, and also in hydrocephalus, &c.

The contractility of texture is accommodated in the fibrous system, to the degree of its extensibility; as it cannot suddenly be distended, it cannot suddenly contract when it ceases to be distended. This fact is remarkable in the division of a tendon, of a portion of aponeurosis,

of a ligament laid bare in a living animal, in an incision of the dura-mater, to discharge blood effused under it, &c. In all these cases, the edges of the division undergo a separation hardly perceptible; thus in the rupture of the tendons, the separation being produced, not by the contraction of the divided extremities, but only by the motions of the limb, the contact is effected by the position in which in the natural state this tendon is not drawn: whilst in a divided muscle, not only this position is necessary, but that in which there is the greatest possible relaxation, and yet oftentimes contact is not effected. If whilst a muscle is stretched, we cut its tendon in a living animal, the end attached to the fleshy fibres separates a little from the other by the retraction of these fibres; but that which is attached to the bone remains immoveable, so that there is then but one cause of separation to this, whereas there are two in a divided fleshy part. If we cut a tendon when the muscle is relaxed, its ends remain in place.

The contractility of texture is evident, however, at the end of some time, in the fibrous system, especially when the organ has been first stretched; for, when it is divided in its natural state, it is always hardly any thing. The sclerotica after the puncture of the eye, or after the amputation of the anterior half of this organ, and the evacuation of its humours, the tunica albuginea, the peculiar coat of the spleen and that of the kidney, after the resolution of a tumour that had stretched their respective organs, the fibrous capsules after the discharge of the fluid of articular dropsies, the abdominal aponeuroses after the first and even the second accouchement, the periosteum after the resolution of exostoses, &c. gradually contract and resume their original forms.

III. *Vital Properties.*

There is never in the fibrous system animal contractility, nor sensible organic contractility. Organic sensi-

bility and insensible organic contractility are found there as in all the other organs.

The animal sensibility exists in it in the natural state; but it appears in a peculiar way, of which no system in the economy, I believe, offers an example and which no one has precisely pointed out. The ordinary agents that put it in action, such as the different stimulants, mechanical, chemical, &c. cannot develop it here, unless the organ is in an inflammatory state. The tendons, the aponeuroses, the fibrous membranes, the ligaments, &c. laid bare in operations, in experiments upon living animals and irritated in various ways do not occasion any pain. What has been written on the sensibility of the periosteum, the dura-mater, &c. taken in this sense is evidently contrary to observation. But if the fibrous organs are exposed to a sudden and violent extension, then the animal sensibility is evident in it to the greatest degree; this fact is particularly remarkable in the ligaments, the fibrous capsules, the aponeuroses, &c.

Lay bare an articulation in a dog, that of the leg, for example; dissect carefully the organs that surround it; remove the nerves especially, so as to leave nothing but the ligaments; irritate these with a chemical or mechanical agent; the animal remains unmoved and gives no sign of pain. Then stretch these ligaments, by twisting the articulation, the animal in an instant throws himself down, is convulsed, cries out, &c. Finally cut these ligaments so as to leave only the synovial membrane which exists here without the fibrous capsule, and twist these two bones in an opposite direction; the twisting ceases to be painful. The aponeuroses, the tendons even laid bare and drawn in an opposite direction, produce the same phenomenon. I have frequently repeated these experiments which prove incontestably what I have advanced, viz. that the animal sensibility of the fibrous system, incapable of being brought into action by the

ordinary means, is very evident in the distensions of which they are the seat. Observe that this manner of being excited is analogous to the functions that it performs. Separated in fact by its deep position from every external excitement which can act upon it chemically or mechanically, it has no need, like the cutaneous system for example, of a sensibility which would transmit the impression of it; on the contrary, the most of these organs, as the ligaments, the fibrous capsules, the tendons, &c. being very subject to being distended, stretched and twisted in the violent motions of the limbs, it was necessary that they should communicate to the brain this kind of irritation, the excess of which might without this become injurious to the articulations or the limbs. Observe how nature accommodates the animal sensibility of each organ to the different excitements it may experience, to those especially which would become dangerous if the mind was not informed of them; for this vital power is the essential agent by which the animal watches over its preservation.

It is to this sort of sensibility of the fibrous system that must be principally attributed, 1st, the acute pains that attend the production of luxations; 2d, those more severe ones which patients experience in the extensions necessary to reduce them, especially when, as in those of long standing, we are obliged to employ considerable force; 3d, the intolerable suffering of the punishment that consisted in drawing a criminal with four horses; 4th, the painful sensation which arises from twisting, which is occasioned by a stretching of the spinal column and consequently of its ligaments, by turning the head too quickly, &c.; 5th, the acute pain that those experience immediately before the accident who break a tendon, a pain which ceases in part when the rupture takes place; 6th, that less sensible pain which we feel when any tendon, the tendo Achillis for example, is from a bad position too much

stretched; 7th, the great increase of pain that is experienced, when a swelling exists under an aponeurosis, which being unable to yield, is very powerfully raised; 8th, the painful sensation we feel in the ham when we wish to force the extension of the leg, by which we stretch the two oblique ligaments destined to confine this extension, &c. &c.

It is without doubt to the insensibility of the fibrous organs to one kind of excitement, and their sensibility to another, that must be referred the contradictory results of the experiments of Haller on the one part, and those of his antagonists on the other, upon the dura-mater.

Character of the Vital Properties.

The vital activity is much greater in the fibrous, than in the osseous and cartilaginous systems. This is proved very evidently, 1st, by the degree of animal sensibility which we have just observed in it, and which is foreign to the other two systems; 2d, by the much greater disposition of this system to become the seat of pains more or less frequent, and especially of inflammation, &c.; 3d, by the much more acute character that this affection has in it, as we see in acute rheumatism, which principally affects the fibrous parts of the great articulations of the axilla, the hip, the knee, the elbow, &c. the aponeurotic part of muscles, &c.; 4th, moreover, by the great mobility of rheumatic pains, which go with astonishing quickness from one place to another, which consequently suppose a great quickness in the alteration of the vital forces of the different parts of this system; 5th, by the greater rapidity of its cicatrization; thus by laying bare fractures made for the purpose in animals, I have constantly observed that the fleshy granulations coming from the periosteum and the medullary organ, are all formed, whilst those furnished by the bone itself have hardly commenced. I would observe in regard to this cicatriza-

tion, that the parts of the fibrous system in which the greatest number of blood vessels enter, as the periosteum, the fibrous membranes, the capsules, &c. are the most capable of this phenomenon, which takes place with much more difficulty in those where little or scarcely any blood goes, as in the tendons, the ends of which are very slow in uniting; 6th, we may finally be convinced of the difference of vitality of the fibrous system and that of the preceding ones, by the progress of an exostosis compared with that of periostosis, or a swelling of the dura-mater, &c. Yet there is still in respect to the vitality a remarkable slowness in this system. We see it especially in certain affections of the limbs, in which gangrene takes place, and makes, like the inflammation that precedes it, rapid progress in the cellular texture, the muscles, &c. whilst that, as I have said, the tendons that have been laid bare do not alter until some time after, and are remarkable for their whiteness in the midst of the general blackness or lividity.

The fibrous system presents a remarkable phenomenon; it is that it hardly ever contributes to the formation of pus. I do not know that after inflammations of this system, purulent collections have been ever observed. Rheumatism, which is ranked with the phlegmasiæ, is never accompanied by these collections; some gelatinous extravasations only have been found around the tendons. That which was formerly taken for a suppuration of the dura-mater in wounds of the head, is very evidently a purulent oozing from the arachnoides, analogous to that of all the other serous membranes. Why does this system refuse, or produce pus with so much difficulty, or why is it not as much disposed to do it as most of the other systems? I know not. Nor do I know that in the midst of the cartilages collections of this fluid have been found. The inflammations of the cartilaginous system are remarkable, because they rarely or never terminate by suppuration.

Sympathies.

All the kinds of sympathies are observed in the fibrous system. Among the animal sympathies, the following are some of sensibility. 1st. In certain periostoses which occupy but a small surface, the whole of the periosteum of the bone that remains sound, becomes painful. 2d. After a puncture, or bruise of the periosteum, the whole of the limb often swells and becomes painful. 3d. In the affections of the dura-mater, the eye is frequently affected, and cannot bear the light, a phenomenon which may also depend on the communication of the cellular texture, but which is certainly sometimes sympathetic. 4th. When we make extension to reduce a luxation, and the articular ligaments consequently suffer much, the patient often complains of pain in a very distant part of the limb, &c.

Contractility is also brought into action in the animal sympathies of the fibrous system. 1st. The puncture of the centre of the diaphragm causes, it is said, in the facial muscles, a contraction which produces a sardonic smile. 2d. The injury of the aponeuroses, the stretching of the ligaments in the luxations of the foot and the tearing of the tendons, are frequently accompanied by convulsive motions of the jaws and even well marked tetanus. 3d. A splinter fixed in the dura-mater produces contractions in the different muscles of the economy. 4th. In injuries of the albuginea and the external aponeuroses, we often observe similar phenomena.

In the organic sympathies of the fibrous system, it is sometimes the insensible organic contractility that is brought into action, and sometimes the sensible organic contractility; the following are examples of the first. 1st. The dura-mater being inflamed, the inflammation which always supposes an increase of the tonic forces or of the insensible organic contractility, is often discoverable in the pericranium and vice versa. 2d. The irrita-

tion of a considerable extent of the periosteum often makes the medullary organ inflame and suppurate. 3d. The articular ligaments being stretched by twisting, all the neighbouring parts, and frequently the whole limb, swell and become a centre of irritation in which all the vital forces of life, insensible contractility in particular, are found much more raised than usual, &c.

At other times it is the sensible organic contractility which is brought into action. 1st. We often observe in the operation for cataract by depression, that the wound of the sclerotica occasions sympathetic vomitings, risings of the stomach, intestines, &c. 2d. A violent pain in any part, in the fibrous system in particular, increases very much the sensible organic contractility of the heart and thus produces from sympathy an acceleration in the motion which it gives to the blood. 3d. I have seen a man in whom Desault reduced a luxation, and who, from the great pain which the stretching of the ligaments gave him, was unable to retain his fœces, so great was the contraction of the rectum.

We see that in these sympathies, it is sometimes the fibrous system which exerts its influence upon the others, and sometimes they exert their action upon it. It is principally when it is drawn, when the peculiar kind of animal sensibility which it enjoys is put into action that it occasions in the whole economy a remarkable sympathetic derangement. I presume the ancients considered as nerves all the white parts, the ligaments, the tendons, &c. on account of the very serious accidents they had observed from their stretching in sprains, in complicated luxations of the knee, the elbow, the ankle, luxations which can never be produced without a violent stretching of many ligaments, of aponeurotic and tendinous parts, &c. A stroke of a sabre which divides the ligaments of the tarsus, a body which bruises them, produce consequences much less serious, than a false step that

twists them. This leads us to an important general consideration, the truth of which is proved by the examination of the other systems; viz. that it is the predominant vital property in a system, which is especially brought into action by sympathies. As the animal sensibility, capable of responding to the agents of distension, is here the most strongly marked, it is this that performs the principal part in the fibrous sympathies.

ARTICLE FOURTH.

DEVELOPMENT OF THE FIBROUS SYSTEM.

I. *State of the Fibrous System in the first age.*

In the midst of the mucous state of the embryo, we cannot distinguish the fibrous organs. All is confounded; it is not until many other organs are formed, that we discover any traces of them. Those in the form of membranes appear at first like transparent nets; those arranged in fasciæ seem to be a homogeneous body. In general the fibres are not distinct in the first age; the aponeuroses, the fibrous membranes, the tendons, &c. do not exhibit any trace of them; all then seems to be uniform in the texture of the fibrous organs. In the fœtus of seven months, we begin to distinguish the white fibres. Few at first, and distant from each other, they gradually approximate after birth, are arranged in a parallel manner, or cross in different directions, according to the organ which they finally possess themselves of entirely

at a certain age. It is especially on the phrenic centre of the diaphragm, the dura-mater, the aponeurosis of the thigh, that we easily make these observations.

As the fibres are developed in the fibrous organs, they have more resistance and hardness. In the fœtus and in the first years, they are extremely soft and easily yield. Their whiteness has a tinge wholly different from that of a more advanced age; they are of a pearly white. It is only gradually that they arrive at that degree of force that especially characterizes them.

It is to this softness, this want of resistance of the fibrous system in the first years, that the following phenomena must be attributed. 1st. The articulations yield at this age to motions which the stiffness of the ligaments afterwards renders impossible; all extensions can then be carried beyond their natural degree. We know that it is at this period that tumblers begin to practice; they would never be able to execute those extraordinary motions, which astonish us, if habit did not preserve in them from infancy the power of these motions. 2d. Luxations are in general rare in the first age, because the fibrous capsules yield and do not break. 3d. Sprains have then less serious consequences. 4th. The inflammatory swellings under the aponeuroses are rarely susceptible of those strangulations oftentimes so severe at the adult age. 5th. This softness of the fibrous system accommodates itself also in the tendons, the ligaments, the aponeuroses, &c. on the one hand to the multiplicity and frequency, and on the other to the want of power of the motions of the infant.

I would remark, that although the fibrous system has in the first age a softness of texture nearly uniform in all the parts that belong to the same order, yet it is more or less developed according to the regions in which it is found. In general, when it belongs to the organs that are early developed, as to the brain by the dura-mater, to

the eyes by the sclerotica, &c. it has in proportion more size and thickness ; but it is only in its dimensions, and not in its intimate organization, that these differences then exist.

It is probable that this mode of organization of the fibrous system has an influence, at the period of which we are treating, upon its degree of vitality and consequently upon its diseases. We know that rheumatism, which appears very probably to affect this system, is rarely the attendant of children of the first age ; that in a hundred patients affected with it, there are ninety at least above the age of fifteen or sixteen years.

Subjected to ebullition, the fibrous system of the fœtus and the infant easily melts, but does not take that yellow colour, which it constantly has, when boiled in the adult age ; we know that the jellies made from young animals are much whiter than those from older ones.

II. *State of the Fibrous System in the after ages.*

As we advance in age the fibrous system becomes stronger and more compact ; it remains stationary in the adult age, though the alternate absorption and exhalation of nutritive substances constantly continue. These two functions can scarcely be seen in the ordinary state ; but the first is very apparent when from a contusion or any internal cause, the periosteum, the fibrous capsules, the ligaments, &c. swell. The second in its turn predominates, when the swelling subsides and resolution takes place.

In old persons, the fibrous system becomes more and more compact and contracted ; it yields more slowly to maceration and putrefaction. The teeth of animals that feed upon it, tear it with more difficulty ; the gastric juices act upon it less easily. Spallanzani has observed, that the tendons and aponeuroses of old animals were

much more indigestible than those of young ones. With age, the force of the fibrous texture increases; but its softness diminishes; hence the difficulty of the motions, from its stiffness. The ligaments and the fibrous capsules do not allow the articular surfaces to separate easily from each other; the tendons bend with difficulty; when we pass externally on places where they are directly under the integuments, we perceive that they are hard, not supple, &c. It requires a long time to soften them by ebullition. The whole fibrous system becomes yellow. We should say that it approached then that state in which it is compact, semi-transparent and has the horny hardening to which desiccation reduces it; so that if we could suppose this system going through quicker than the others the different periods of its decrease, all the motions would cease from the rigidity of the ligaments, tendons and aponeuroses, though the energy of contraction might still subsist in the muscles.

III. *Preternatural Development of the Fibrous System.*

We have seen that different productions belonging, by their nature, to the osseous or cartilaginous systems, are sometimes preternaturally developed in certain parts. Morbid anatomy also shows us productions, in which the fibrous appearance is very evident. I have many times made this observation in tumours of the womb, the fallopian tubes, &c. Instead of the lardy matter which is so common in these organic affections, we see one or several masses of fibres, very distinct, yellow, &c. I cannot however say that these excrescences belong essentially, by the substances that compose them, to the fibrous system, not having made upon them, experiments similar to those which I have made upon the organs of this system.

ARTICLE FIFTH.

OF THE FIBROUS MEMBRANES IN GENERAL.

After having considered the fibrous system in a general manner, as it relates to its organization, its life, its properties and its nutrition, I shall now examine it more particularly in the great divisions it offers, and which we have pointed out above. I begin with the fibrous membranes.

I. *Forms of the Fibrous Membranes.*

These membranes which comprehend, as has been said, the periosteum, the dura-mater, the sclerotica, the albuginea, the peculiar membrane of the spleen, the kidneys, the corpus cavernosum, &c. are almost all destined to form external coverings, kind of sacs in which are contained the organs they invest.

These organs are not, like those around which the serous surfaces are spread, as the stomach, the intestines, the bladder and the lungs, subject to alternate dilatations and contractions. This would not accord with their degree of extensibility. They are fitted exactly to the form of these organs, and have none of those numerous folds which we see in the serous membranes, if we except however the dura-mater. Their two surfaces are adherent ; a character which distinguishes them especially from the preceding membranes, as well as from the mucous.

One of these surfaces, intimately united to the organ, appears to send various elongations into it, which identify at first view its existence with that of the membrane.

Many fibres detached from the albuginea, from the covering of the corpus cavernosum, from the peculiar tunic of the spleen, &c. or rather adhering to these tunics, penetrate the respective organs of these membranes, and crossing there in various directions, form as it were the outline and frame, around which are arranged and supported the other constituent parts of these organs, which seem from this to have the external membranes for a mould ; as we see when these moulds are removed, irregular vegetations shooting up here and there. The callus, in displacements too great to allow the periosteum to extend over the divided surfaces, is rough and uneven. The form of the testicle alters, when the albuginea has been divided at any part. This adherence of the fibrous membrane which covers different organs, to the internal elongations of these organs, and the fibres which compose their outline, has made anatomists believe that the nature of one was the same as that of the others, that these were but elongations of the membrane. I thought so when I published my Treatise on the Membranes ; but new experiments have since convinced me of the contrary.

I am confident that the membrane of the corpora cavernosa belongs to the fibrous system alone. The internal spongy texture, contained in the cavity of this membrane, has not the nature of it, is not as all anatomists say an elongation of it. The spongy texture is not made by laminæ, which, according to the common expression, are detached from the membrane and produce it by their interlacing. This is a separate body, unlike in its life and its properties.

By exposing a corpus cavernosum to ebullition, I have evidently observed this difference ; the external membrane does, like all the fibrous organs, become thick, yellowish, semi-transparent, then melts more or less into gelatine ; the spongy texture, on the contrary, remains white, soft, does not increase in size, hardly crisps at all

from the action of fire, exhibits, in a word, an appearance which I can compare to no texture treated in the same way by ebullition.

Maceration also answers very well to distinguish these two textures. The first yields but slowly to it; its fibres remain a long time distinct; they have still their natural arrangement, when the second is already reduced to a homogeneous, reddish pulp, in which nothing fibrous, nothing organized can be any longer traced. In general, it appears that the spongy texture of the corpora cavernosa is their essential part, that in which the great phenomena of erection take place, that which animates the peculiar kind of mobility which distinguishes it from the other organs. The fibrous shell is only accessory to its functions; it is but a covering; it is only formed to obey in erection the impulse which is communicated to it.

When we expose the corpus cavernosum to the action of the nitric acid, the spongy texture, freed from the blood it contained, becomes of a much deeper yellow than the fibrous membrane; this enables us to distinguish them clearly from each other.

By exposing the testicle to the action of boiling water, we also observe that its internal texture assumes an aspect wholly different from that of its external membrane; it becomes of a deep brown, whilst the other remains white; it does not assume the gelatinous appearance in so decided or in so prompt a manner as that of the corpus cavernosum.

Subjected to maceration, the testicle is also wholly different in its covering and in its internal texture.

The surface of the fibrous membranes, opposite to that which corresponds to their organ, is joined to the neighbouring parts, sometimes in a loose manner, as the covering of the corpus cavernosum, sometimes by very tight bands, as the dura-mater. In general the membranes, and even all the fibrous organs, have a singular tendency

to unite intimately to the serous and mucous surfaces. We find examples of this in the serous membranes in the union of the dura-mater with the arachnoides, of the albuginea with the tunica vaginalis, and the fibrous capsules with the synovial. Such is the intimacy of this adhesion, that the most careful dissection cannot destroy it in adult age. In infancy, it is much less, as we see very well especially in the relation that exists between the base of the pericardium and the phrenic centre, a relation which is such, that we can with ease separate in the first age the two surfaces which are rather contiguous than continuous, whilst in the after ages we are unable to do it.

As to the union of the mucous surfaces with the fibrous, when they are found contiguous, they are entirely confounded; this is observed in the pituitary membrane, in that of the sinuses, of the ear, &c. The perichondrium of the larynx and of the trachea is only a part of their internal membrane. In all these parts, the periosteum so intermixes with the mucous surface, that it is impossible to separate them, and they are removed together from the bone, which then remains bare. The vas deferens, the fallopian tubes, the ureters, &c. are also very evidently fibro-mucous.

II. *Organization of the Fibrous Membranes.*

The fibrous membranes have in general a very compact texture, of a remarkable thickness; they are formed only of a single lamina. The dura-mater seems to be an exception to this rule, as its folds form the falciform process and the tentorium cerebelli; but except at the place of the sinuses, it is difficult and even impossible, to find two distinct laminæ.

These membranes have more vessels than all the other divisions of the fibrous system; they are perforated by a great number of foramina for the passage of these vessels,

most of which only pass through them, and afterwards go to the organs they cover. These foramina, each of which is larger than the branch it transmits, form also a character of the fibrous membranes, distinct from the serous, which are always folded up, and never open to allow the vascular system to penetrate their respective organs.

The particular description however of the membranes of which we are treating, will be added to that of the organs they surround. I shall except the periosteum, whose description belongs to and may be made in a general way, whether because clothing the whole osseous system, we cannot consider it separately, or because, as I have said, it is the centre from which arise and to which go all the organs of the fibrous system, so that its functions relate still more to this system than to that of the bones.

III. *Of the Periosteum. Of its Form.*

This membrane surrounds all the bones. Hard, resisting, of a grey colour, it forms for them a covering which extends everywhere, except where the cartilages cover them. Its thickness is remarkable in infancy; it is thinner in proportion in the adult and becomes more firm and compact.

The ancients described it as extending from one bone to another over the articulation, and thus forming a continuous sac for the whole skeleton. This idea is incorrect. At the junction of the bones, the periosteum intermixes with the ligaments which serve it as a means of communication, and it is in this way only that we can understand its continuity. The crown of the teeth is destitute of it, as well as all the osseous productions that grow upon the head of certain animals.

The periosteum is feebly united to the bone in infancy; it can then be separated with great ease, especially on

the middle part of the long bones. In the adult, as the calcareous substance gradually encrusts its most internal fibres, the adhesion becomes very strong; it is extreme in old age, in which this membrane is often reduced to a very delicate layer by the progress of ossification. The constant pressure exerted by the muscles in their contractions, can also have a little influence upon this adhesion. Various elongations pass from the periosteum to the bone. They are much more numerous at the extremities of the long bones and upon the short bones, than upon the middle of the long bones, or the broad ones; which may easily be conceived of, from the much greater number of foramina in one than the other part. These elongations accompany the vessels, line the canals which pierce through the bone, are lost in those which terminate in its substance, do not penetrate the medullary cavity, and confined to the osseous texture alone, establish, between it and the membrane from which they arise, immediate relations.

It is the destruction of these relations, when the periosteum is diseased or destroyed for a considerable extent, that produces the death and separation of the bone. There is however this difference between this phenomenon and the death of the bone by the injury of the medullary membrane, that if this is disorganized, necrosis seizes upon the whole bone, whilst if we irritate and tear the periosteum in the middle part of a long bone, for an extent nearly equal to that of this medullary membrane, the external laminæ of the compact texture alone are detached by exfoliation, and the bone remains the same. I have made this experiment the year past upon two dogs. As to that which consists in removing the periosteum, not only from the middle part, but from the whole surface of the bone, I do not know that any one has been able to try it; it has appeared to me impossible; it might be practicable, but the animal would soon die from the

extent of the injury, and thus we could have no result from it.

The relations of the periosteum with the neighbouring organs vary remarkably. In the greatest number of bones, there are muscles that slide upon it; the cellular texture unites it to them more or less closely according as the motions are more or less considerable. In consequence of inflammations, it loses this laxity, and often all motion ceases.

Organization of the Periosteum.

The direction of the fibres of the periosteum is nearly analogous to that of the bones, the long bones especially as well as the short; but it has not the radiated structure of the flat bones that it covers. These fibres placed upon each other, have different lengths; the superficial ones are the longest; those which correspond immediately with the bone run but a short distance. In general all become very evident in some diseases of the bones. I recollect among other examples of the preternatural development of the fibres, a man affected with elephantiasis, and at the same time a swelling of the compact texture of the tibia, which was of a remarkable thickness. The periosteum of this bone was very thick, and adhered so little to the bone, that the slightest effort was sufficient to raise it in its whole extent, and its fibres were so distinct, that it might have been taken, when separated from the bone, for a portion of plantar or palmar aponeurosis.

The periosteum borrows its vessels from those of the neighbouring parts. Their innumerable branches ramify in it ad infinitum, form there a net-work, which injections, especially in infants, make very evident, they are afterwards lost in it, or penetrate the compact texture of the bone, or return to the neighbouring parts to form anastomoses.

This membrane receives, as we have said, the insertion of almost all the fibrous system, of the tendons, the

ligaments and especially the aponeuroses. This insertion has no connexion with the bone in infancy; but ossification soon seizing upon the most internal laminæ, all the fibrous organs appear to be identified with the bone in the adult. I would observe that this arrangement coincides with the prodigious power of drawing that the muscles, having become more developed, often exert at this age, and which only spent upon the periosteum, as it would have been without its ossification, would not have found in it a sufficient resistance, whereas acting also upon the bone, it moves it without endangering its covering. The general organization, the properties and the life of the periosteum are the same as those of the fibrous system; I shall not treat of them.

Development of the Periosteum.

In the fœtus, this membrane is soft, spongy, containing much gelatinous fluid; it melts easily in water; its fibres are not distinct; they become so as we advance in age, and at the same time the softness diminishes and the resistance increases. The periosteum in old age has extreme tenacity; it resists ebullition almost as much as the ligaments; those who prepare skeletons know this very well. It tears in various places, because its fibres in contracting are detached from the bone; but what remains becomes with great difficulty gelatinous.

Functions of the Periosteum.

The periosteum defends the bones which it covers from the impression of the moveable parts that surround it, from that of the muscles, of the arteries, whose pulsation would wear them, as happens in certain aneurismal tumours near the sternum, the vertebræ, &c.

It is a kind of parenchyma of nutrition in reserve, if I may so express myself, always ready to receive the phosphate of lime, when it cannot be carried upon the bone that has become diseased; hence natural and artificial necroses which never take place in the teeth, from the want of this membrane. These little bones have caries and various alterations, but not true necrosis.

We cannot doubt that the internal laminæ of the periosteum are successively ossified, and thus contribute not a little to increase the bone in thickness, when its increase in length is finished. I would observe upon this subject, that not only it, but all the fibrous system, has a singular affinity with the phosphate of lime. Next to the cartilaginous system, it has the greatest tendency to be encrusted with it, no doubt because its kind of general vitality, of organic sensibility in particular, has much analogy with that of the bones. Where the tendons in sliding upon the bones experience great friction they become osseous. The dura-mater and the tunica albuginea are very often ossified; the sclerotica serves as a parenchyma for much earthy substance in birds, which in consequence have it extremely hard.

The periosteum has no connexion with the formation of the bones; it is only accessory to that of the callus; it is a kind of limit which circumscribes within its natural bounds the progress of ossification, and keeps it from irregular aberrations. Does it prepare the blood which serves to nourish the bones? This question cannot be settled by any experiment; but we are sure that the vital properties which it enjoys, do not enable it to accelerate the circulation of the blood arriving at the bones, as some authors have thought.

It seems to me moreover that they have described the periosteum too exclusively in relation to the bones; no doubt it is necessary to these organs; but perhaps it performs in relation to the fibrous organs a still more impor-

tant part. If nature has placed it everywhere on the osseous system, it is probably in great part, as I have said, because it finds in this system a general, solid and resisting support, which enables it to resist the various drawings, that the whole fibrous system makes upon it, drawings which are sometimes communicated to this last system. This is a new point of view in which the periosteum should be described, and it will yield much more to general considerations, than that in which Duhamel, Fougeroux, &c. have considered this membrane.

IV. *Perichondrium.*

We find on all the non-articular cartilages a membrane exactly analogous to the periosteum, and which is called perichondrium. The larynx, the ribs, &c. exhibit it in a very evident manner ; it is delicate, with fibres interlaced in all directions, less closely united to the organs it covers, than the periosteum is to the bones, because the cartilages having on their surface less numerous foramina, it does not send to them as many fibrous elongations ; hence a less intimate relation between the life of the perichondrium and that of the cartilage, than between that of the bone and its periosteum.

I have twice in a young dog removed from the thyroid its external membrane, and closed the wound immediately, which has been cured without apparent alteration in the organization of the cartilage : at least it has continued to perform its functions. The same experiment might easily be made on the cartilages of the ribs ; I have not attempted it. The perichondrium has appeared to me in many injections to contain fewer blood vessels than the periosteum ; its uses are analogous to those of this last membrane.

ARTICLE SIXTH.

OF THE FIBROUS CAPSULES.

The fibrous capsules are infinitely more rare in the economy, than they have heretofore been thought to be. The scapulo-humeral and the ilio-femoral articulations are almost the only ones furnished with them. Elsewhere there is nothing scarcely but synovial membranes.

I. *Forms of the Fibrous Capsules.*

These capsules form a kind of cylindrical sac open at the two extremities, attached by the circumference of its openings, around the superior and inferior articular surfaces, intermixing at its insertion with the periosteum. They are so much the more loose, as the motions of the articulations are the more extended; that of the humerus, for example, allows a much greater separation of the osseous articular surfaces, than that of the femur; their length in fact is almost the same. Now, as on the one hand, the neck of the first bone is much less than that of the second, and as on the other, both these capsules are inserted at the base of this neck, it follows that the extent of the separation is in the inverse ratio of the length of the articular necks.

Much cellular texture surrounds these capsules externally, which the tendinous fibres and even the tendons coming from the neighbouring muscles, strengthen remarkably. They are sometimes open to allow tendons to pass which are inserted in the bone between them and the synovial membrane, an example of this is seen in the scapulo-humeral articulation for the sub-scapularis. An-

atomists who have observed the insertion of the tendons in the capsules, have concluded from it, that the muscles of these tendons were destined to prevent the capsule from being pinched by the articular surfaces in motion. This appears to me improbable; but at least the muscles are destined to prevent the looseness of the capsule during the great motions, which would have been weakened by this looseness; thus there are many of this kind of muscles at the humeral capsule, whilst we see none of them at the femoral, which is, as I have said, much less loose. Within, the capsules are very closely united to the synovial membrane, especially in adults; for in infants, this adhesion is less. Near their extremity however this relation does not exist, because the synovial membrane being reflected upon the cartilage, a triangular space is left between it and the capsule which is attached to the bone, and as this arrangement continues all round the articulation, there results from it a kind of circular canal, filled with cellular texture, and covered with vessels, which I have sometimes distended with an injection pushed into a small opening made for the purpose.

The intimate union of the capsule with the synovial membrane prevents its folds and also its contusion in the great articular motions.

II. *Functions of the Fibrous Capsules.*

Why are the fibrous capsules found only around the first kind of articulations? The reason of it is plain; as these articulations have in all directions motions nearly equal, they should have on all sides an equal resistance, whilst the others moving in one or two directions only, the ligaments were unnecessary except at certain places, to limit these motions. Hence why for example, the fibrous system is spread out like a membrane around the ilio-femoral articulation, and collected into distinct fasciæ

around the femoro-tibial, where the synovial membrane is almost everywhere bare.

We understand from all that has been said, that the only use of the fibrous capsules is to strengthen the articular relations, and that this use has no connexion with synovial exhalation.

When in luxations not reduced, the head of the bone has left the articular cavity, a new membrane is formed around it in the cellular texture which serves for a capsule; but this membrane has not the texture of the former one. I have observed in two subjects, that no fibre could be distinguished in it, that its texture was very analogous to that of the different cysts that are often found in many parts of the economy, of those especially that form round foreign bodies, the presence of which is not a cause of suppuration, and that consequently these preternatural capsules belong rather to the class of serous than to that of the fibrous membranes.

ARTICLE SEVENTH.

OF THE FIBROUS SHEATHS.

The fibrous sheaths are, as we have said, partial or general.

I. *Partial Fibrous Sheaths.*

The partial sheaths destined to a single tendon are of two sorts; one runs a long course; such are those of the flexors of the foot and the hand, which correspond to the

whole concave surface of the phalanges; the others form only a kind of rings, in which a tendon is reflected, an example of which is seen in the great oblique muscle of the eye.

All in general form a semi-circle and make half of a canal which the bone completes; so that the tendon slides in a canal half osseous and half fibrous. This canal is lined by a synovial membrane, the attachment of which to the fibrous sheath is equal to that of the articular synovial membrane to its capsule. By their external surface, the fibrous sheaths correspond with the neighbouring organs, to which they are united by a loose cellular texture.

All these sheaths are of a very dense and compact texture; they are stronger in proportion to the effort which the tendons can exert upon them, than the fibrous capsules are in relation to the different impulses which the bones can communicate to them and which tend to rupture these capsules. They are confounded with the periosteum at their two edges. Those of the flexors unite also by their extremity with the expansion of the tendons; hence the very considerable fibrous interlacing that is observed at the extremity of the last phalanges.

In the limbs, the flexors only have these sheaths; the extensors are destitute of them. This arises first from this, that there are two tendons of the first kind to each finger, whilst there is only one of the second, and that consequently more force is necessary to retain them in the first direction. In the second place, each extensor tendon receives on its sides the insertion of the small tendons of the interosseous muscles and the lumbricales, which by drawing it in an opposite direction in the great motions, retain it in its place, and thus compensate for the fibrous sheaths that are wanting. Finally the efforts of the extensors are much less than those of the flexors, of which they are as it were but a kind of moderators.

II. *General Fibrous Sheaths.*

The general sheaths are seen especially at the wrist and the instep, where they have the name of annular ligaments. They are destined to confine many tendons together. As in these two places, all those of the hand and the foot pass in a very narrow space, it is necessary that they should be strongly supported. Besides, these sheaths serve also sometimes to change their direction, as we see in those that go to the thumb, whether to its palmar or its dorsal face, and which evidently make an angle at the place of their passage under the sheath. The tendons of the little finger have also an analogous arrangement.

These sheaths exhibit also two great modifications; in the one, as on the anterior part of the wrist, all the tendons are found contiguous, separated only by a kind of loose membrane which is placed between them; in the others, as on the posterior part of the wrist, under the general sheath, are found small fibrous partitions, which separate the tendons from each other. In general, the resistance of these sheaths is very considerable.

ARTICLE EIGHTH.

OF THE APONEUROSES.

We have distinguished aponeuroses as being of two classes, those for covering and those for insertion.

I. *Of the Aponeuroses for Covering.*

The aponeuroses for covering are general or partial.

Aponeuroses for General Covering.

They are found around the limbs, whose muscles they tie down. The arm, the fore-arm and the hand, the thigh, the leg and the foot, are provided with them.

Forms.

They are, in their conformation, analogous to the form of the limb, which they in part determine, and which they especially maintain, by preventing the displacement of the subjacent parts, a displacement which would continually take place, from the laxity of the cutaneous organ. Their thickness varies. In general, the greater the number of the muscles they cover, the greater their thickness; hence why the aponeurosis of the fascia lata is superior in this respect to the brachial; why that of the fore-arm is thicker in front than behind; why the plantar and palmar are so considerable, whilst hardly any fibres are found on the back part of the foot and the hand. There are however some exceptions to this rule; for example, the aponeurotic covering of the posterior part of the leg is not in proportion to the power of the gastrocnemei and solæus muscles; thus these muscles are more than all the others exposed to displacements, frequently very painful, which constitute cramp, and which it is necessary to distinguish from the pains or numbness which result from the compression of one of the nerves of the lower limbs, as of the sciatic, or the external plantar, a compression produced by a bad position, or any other analogous cause.

Externally, the aponeuroses of the general covering are contiguous to the integuments. A very loose texture unites them, so that the latter can easily slide over them in external pressures. Immoveable between these motions and those of the muscles, they entirely separate them; so that the skin and the muscles that correspond

to it, have not, in this respect, any influence upon each other.

Within, these aponeuroses are in general loosely joined to the muscles by cellular texture. Here and there they send between the different muscular layers numerous elongations, which are afterwards attached to the bone, and which, at the same time that they furnish points of attachment, increase the solidity of the covering of the limb.

Tensor Muscles.

The aponeuroses for general covering have almost all one or two particular muscles that are inserted in them in whole or in part, and which are destined to give them a degree of tension or relaxation proportioned to the state of the limb. This arrangement is remarkable in the insertion, 1st, of the great dorsal and pectoral muscles in the brachial aponeurosis; 2d, of the biceps in that of the fore-arm; 3d, of the palmaris longus in the palmar; 4th, of the glutæus maximus and of the fascia lata in the aponeuroses of that name; 5th, of the semi-tendinosus, semi-membranosus and biceps in the tibial.

As in the great motions of the limbs, in which all the muscles are the most liable to be displaced, these are necessarily in action, they distend powerfully the aponeurosis, which thus reflects the motion that is communicated to it, and resists especially every displacement. When the limb is at rest, the tensor muscles cease their contraction, and the aponeurosis is relaxed. I would observe, that the muscles attached to the fibrous capsules, as to that of the humerus, for example, perform for them the same functions, that the tensor muscles do for their respective aponeuroses.

The colour of these last is a brilliant white; in this respect they differ from all the fibrous organs thus far examined, and are analogous to the tendons, from which

they differ a little however in their nature; in fact, they yield less quickly to maceration and ebullition; their fibres are more stiff and resisting. There are no aponeuroses exactly like the tendons, except those which are essentially formed by their expansion or which are at their origin, as those spread upon the anterior rectus of the thigh, those which are concealed in the fleshy fibres of a muscle, and afterwards go out of it to become a tendon. In certain parts of the limbs, as at the top of the arm, for example, the aponeuroses of general covering are insensibly lost in the cellular texture, without our being able to draw the line of demarcation. This arrangement is almost peculiar to the fibrous system; at least I know of no one which thus intermixes and loses its fibres in the cellular texture; it is so much the more remarkable, as the nature of the two textures is essentially different; they do not yield the same products, and they have not the same organic arrangement.

The fibres of the general aponeuroses are only interlaced in two or three directions; this interlacing is almost always very evident to the naked eye. But I have observed that by plunging an aponeurosis into boiling water, and leaving it there for some time, its fibres, in the horny hardening they then undergo, become still much more evident. This observation is moreover applicable to the whole fibrous system, to its organs especially, whose texture but little apparent seems at first view to be homogeneous. In this way, we distinguish very well the fibres of the dura-mater.

Functions.

The constant compression made upon the limbs by their aponeuroses, besides the uses pointed out, has that of favouring the circulation of the red and white fluids. Thus varices, which are very rare in the deep veins which accompany the arteries, are extremely common in the

superficial ones placed beyond the influence of this compression, which art imitates by the application of tight bandages, the effect of which is so advantageous in many external diseases arising from the want of tone, and the relaxation of the parts. I have uniformly observed that the serous infiltrations always begin in the sub-cutaneous cellular texture, that it is only in an advanced stage of dropsy, that we find effusion in that which is under the aponeuroses, and that in general it does not contain as much serum in proportion as the other. In most of the great distensions of dropsical limbs, when the skin is removed and the subjacent water has flown off, the limb covered by its aponeurosis, is scarcely larger than in the ordinary state. The muscles not protected by these coverings, like those situated on the sides of the abdomen for example, become dropsical much more easily.

Aponeuroses for Partial Covering.

These aponeuroses are met with in insulated parts, in front of the abdomen, on the head, the back, &c.; they are usually destined to retain in place a certain number of muscles which they do not surround on all sides, like the preceding, but with which they correspond only in one direction. Their thickness is much less than that of the preceding ones; it is adapted to the efforts that they are to support.

All have a tensor muscle which proportions their degree of relaxation or of tension to the effort of the neighbouring muscles. The anterior rectus, by means of its intersections, and the pyramidalis, perform this office for the abdominal aponeuroses; the small posterior dorso-costals do it for that which covers the muscles of the vertebral foramina; the auricular, the frontal and the occipital for that of the cranium.

The aponeuroses of covering, whose use is limited to one muscle only, like that, for example, of the temporal,

want the tensor muscle, and have consequently the same degree of tension always; it is on this account no doubt that they have a very compact and thick texture, as that which I have just mentioned is an example.

In general, the use of all the aponeuroses of covering whether general or partial, relative to the compression of muscles, is required by the displacements of which they would be susceptible in contracting, displacements evident, 1st, when we place the hand upon a muscle in action, and which is destitute of aponeurosis, as the masseter; 2d, when a wound having injured a considerable part of an aponeurosis of covering, the subjacent muscles become accidentally contiguous to the integuments; 3d, when in an animal we lay bare the muscles of a limb, and leave only the cellular texture to confine them, and in this state excite their contraction; 4th, in certain wounds of the muscles happening at the instant of their contraction, it is difficult to probe these wounds, because in their relaxation the muscles taking a different position, the relations change between the parts that formed the two edges of the wound.

Of the Aponeuroses of Insertion.

We have divided into three species the aponeuroses of insertion.

Aponeuroses of Insertion with a Broad Surface.

They are very numerous. Sometimes they arise from the expansion of a tendon, as we see in those of the anterior rectus of the thigh; sometimes, as in the masseter, they derive their origin immediately from the bones. Sometimes it is on one side only that the insertion is made; at others it is on both at the same time, and then they appear like partitions placed between the fleshy fasciæ, which they serve at the same time to separate and

unite, as we observe in the muscles that arise from each of the condyles of the humerus.

These aponeuroses always receive in a very oblique direction the insertion of the fleshy fibres. Their mutual adhesion is intimate; I shall speak of it in treating of the tendons.

They have the great advantage of multiplying prodigiously the points of insertion, without requiring great osseous surfaces. The width of the whole of the temporal fossa would not be sufficient for the masseter, if it was inserted by separate fibres. By means of the aponeurotic partitions which receive its fibres and are afterwards fixed in the bone, its insertion is concentrated upon one of the edges of the zygomatic arch. Thus in general, all the very strong muscles, whose fibres are consequently very numerous, are crossed by similar aponeuroses, as the deltoid, the pterygoids, &c. are a proof.

Almost all these aponeuroses are exactly like the tendons; many are continuous with them and then their fibres remain in the same direction. In general, it is a character of these aponeuroses not to have their fibres crossed in different directions, like those of the aponeuroses of covering; the reason of it is plain; the fleshy fibres to which they give attachment being all nearly in one direction, or at least not crossing, it is necessary that these should be like them as they are continuous with them.

I have made an experiment which shows very evidently the identity of the tendons with these aponeuroses; it consists in macerating for some days a tendon; it then becomes supple; its fibres separate; by stretching in the direction of its width, it forms a kind of membrane which it would be impossible to distinguish from a true aponeurosis.

Aponeuroses of Insertion in the form of an Arch.

They are much more rare than the preceding. When a great vessel passes under a muscle, nature employs this

means, so as not to interrupt the insertion of the fleshy fibres. The diaphragm for the aorta, the solæus for the tibial artery, exhibit an arrangement of this kind. The insertion is made on the convexity, and the passage of the vessel under the concavity of the arch, both extremities of which are fixed in the bone. It has been thought for a long time that the arteries could be compressed under these arches; and hence the explanation of popliteal aneurisms, of apoplexy by the reflux towards the head of the blood interrupted in the aorta, &c. But it is very evident that by contracting, the fleshy fibres would enlarge the passage, instead of contracting it, since the necessary effect of these contractions is to enlarge in all directions the aponeurotic curve, an effect which would be directly opposite, if their insertion was made at the concavity. These aponeuroses are strongly interlaced and very resisting.

Aponeuroses of Insertion with Separate Fibres.

They are a collection of an infinite number of small fibrous bodies wholly distinct from each other, which seem to be detached from the periosteum, as the threads of velvet go off from their common woof. Each is continuous with a fleshy fibre; so that when by maceration we remove all those fibres, these small bodies become floating and are seen perfectly well, especially when the periosteum which has been detached is plunged into water.

It is evident that this mode of insertion on the part of the muscles requires always broad osseous surfaces, since each fibre has a place of its own; we have an example of it in the superior part of the iliacus, of the anterior tibialis, of the temporal, &c. If all the muscles were inserted in this manner, ten times more surface in the skeleton would not be sufficient to receive them.

ARTICLE NINTH.

OF THE TENDONS.

The tendons are a kind of fibrous cords, intermediate to the muscles and the bones, transmitting to the second the motion of the first, and performing in this function a part wholly passive.

I. *Form of the Tendons.*

Usually situated at the extremities of the fleshy fascia, they sometimes however occupy the middle, as we see in the digastric muscle ; they are almost always found at the most moveable extremity, that which serves for support having aponeuroses for insertion, as we see especially on the fore-arm and the leg, of which all the muscles inserted above by broad osseous or aponeurotic surfaces, terminate below by a more or less slender tendon. From this arrangement result, 1st, little thickness at the extremity of the limbs, and consequently facility in their motions ; 2d, great resistance to external pressures very frequent in this place, the fibrous texture being, as we have said, very resisting ; 3d, the concentration of the whole effort of a muscle oftentimes very thick upon a very narrow osseous surface, and for the same reason the extent and force of the motions of the bone.

The tendinous forms are usually round, no doubt because they are those in which, with the least size the greatest quantity of matter enters. Sometimes however as in the tendons of the extensors of the leg and the fore-arm, they are flat.

Sometimes bifurcated or divided into many secondary elongations, the tendons are inserted into the bones, or receive fleshy fibres in two or many different points. All are covered by a loose texture which allows them to slide easily upon each other, or upon the neighbouring parts. Sometimes this texture is wanting, and then the synovial capsules surround them to favour their motions. Their extremity, in which the fleshy fibres are fixed, receives these fibres differently. Sometimes it is to one side only that they are attached; hence the semi-penniform muscles; at other times it is to both sides at the same time; this constitutes the penniform. Frequently the tendon is buried so deep in them, that it cannot be laid bare, but by dividing them longitudinally.

The adhesion is very great between the fleshy and tendinous fibre. Yet by macerating them a long time or subjecting them to ebullition, they gradually separate from each other. I have observed that in young subjects the union was much less intimate; thus by scraping at this age the tendon with a scalpel, we remove from it the muscle, without its ever appearing again; the polish is almost the same where the fibres are inserted, as where they are naturally wanting. The extremity of the tendon fixed to the bone, intermixes with the periosteum as it usually expands; so that it is with this membrane, and not with the bone itself, that the tendon makes part, because in fact it is the membrane which is of the same nature; thus if it finds an analogous membrane, it fixes to it equally, as we see in the insertion of the straight and oblique muscles in the sclerotica, of the ischio and bulbo-cavernous ones in the membrane of the corpus cavernosum. In general the tendons never unite but to fibrous membranes; the serous, the mucous, every organ in a word, foreign to the fibrous system, is also heterogeneous to them.

II. *Organization of the Tendons.*

The fibrous texture is extremely compact in the tendons; many appear homogeneous at first view; but by examining them with care, we soon distinguish fibres, connected by a small quantity of compact cellular texture. Ebullition renders these fibres very evident; when we plunge suddenly the tendon into boiling water at the place where it has been cut transversely, they become a little thicker at this divided extremity, swell as it were and are thus very evident. At the place where they expand to form an aponeurosis or to unite to the periosteum, these fibres can be distinctly seen without any preparation. On the other hand, as we can always, as I have said, reduce artificially a macerated tendon to an aponeurosis, and as in this state of maceration, soft and loose, it yields to all the forms we wish to give it, it is an excellent means of distinguishing the tendinous fibres. In this experiment so easily repeated, I have never seen the spiral form of the tendinous cylinders, of which some modern authors have spoken. These fibres are in the tendon as at the place where they separate to form an aponeurosis, that is to say in a right line.

Blood scarcely enters the vascular system of the tendons; but in some inflammations, they are wholly penetrated by it. I have seen one of those of the extensors, laid bare in a whitlow, so red, that it had the appearance of a phlegmon. Yet I observed that this colour was not, as in many other inflamed organs, dependant on the small red striæ, an indication that the exhalants are filled with blood; but it was uniform, as for example a body dyed red. In general, it appears that of the whole fibrous system, it is the tendons which have the least energetic degree of vitality, and the most obscure vital forces. By dissecting them in a living animal I have found that they have exactly the same arrangement as in the dead body;

the white fluids that penetrate them do not flow under the scalpel; they are dry and can be removed by layers. They appear to have a very low temperature; for, in general, the degree of heat of an organ is in proportion to the quantity of blood vessels it receives.

If in the body they are at the general temperature, it is only because the neighbouring organs communicate theirs to them. Caloric is not disengaged in their texture.

The tendons have a remarkable affinity to gelatine and even the phosphate of lime; where they slide upon a bone, and where they suffer a great friction, they exhibit a hardness which authors attribute to pressure, by comparing it to the callous hardening of the sole of the feet, but which is owing evidently to an exhalation in the tendinous texture of the two preceding substances, an exhalation which the motion produces and from which arises a real ossification.

It is thus as we have said, that the different sesamoid bones are formed, and the patella in particular, a bone the texture of which evidently differs from that of the others, because in the midst of the gelatine and of the phosphate of lime that penetrate it, there remains in it a part of fibrous texture which is not seized upon by these substances, and which is so considerable that its kind of vitality and organization belong as much and more to that of the fibrous system, than to that of the osseous.

Besides, if we detach the patella or any sesamoid bone, leaving with it a tendinous portion of each side, and expose them to the action of an acid, this calcareous substance is removed, the fibres of the bone are exposed, and we see that they are a continuation of those of the tendon which is then softened.

The muscles of organic life, and most of those which in animal life form the sphincters, are destitute of ten-

dons. This white texture, those silver cords that are found in the heart, have not the nature of the tendons of the limbs.

ARTICLE TENTH.

OF THE LIGAMENTS.

We have divided the ligaments into those with regular fasciæ, and into those with irregular ones.

I. *Ligaments with Regular Fasciæ.*

They are met with in general in almost all the moveable articulations, and especially upon their sides; hence the name of lateral ligaments by which most of them are designated. Some however are foreign to the articulations, as we see an example in that extending from the coracoid to the acromion process, in those which complete the different osseous fissures, the orbitary for example.

These organs form fasciæ sometimes round, sometimes flat, fixed to, or rather intermixed with the periosteum by their two extremities, easily removed with it in childhood, holding to the bone in the adult by the ossification of the internal layers of this membrane.

Their analogy with the tendons is very striking; the external difference is that they hold to the periosteum at both sides, whilst on one side the tendons are contiguous with the muscles. We see sometimes that the same organ is a tendon at one age, and a ligament at another.

This arrangement is remarkable in the inferior ligament of the patella. Yet there are, as we have remarked, differences of composition between them. All result from an assemblage of fibres parallel in the middle, diverging at the extremities, united by a cellular texture more loose than that of the tendons, and which often contains some fatty flakes. This substance is sometimes so abundant in them, that they have an appearance analogous to that of the fatty muscles; I have made this observation on the ligaments of the knee, in a subject elsewhere very thin.

There are some blood vessels in the ligaments. In certain diseases of the articulations, their vascular system is developed in a very remarkable manner, and they are penetrated by a great quantity of blood; no nerve is discoverable in them.

Sometimes the ligamentary texture is changed into a matter like lard, in which every kind of fibre disappears, which rarely returns to it primitive state, and which is met with almost always in organic affections, fatal to the patient.

The ligaments unite strongly the osseous surfaces, prevent their displacement, and yet allow easy motions; a double function which they perform in virtue of a double property, of their resistance on the one part, of their softness and flexibility on the other; sometimes externally. they serve for some muscular insertions.

II. *Of Ligaments with Irregular Fasciæ.*

These are irregular fibres scattered here and there upon the osseous surfaces, without any order, intermixed in different directions between the sacrum and the ilium, upon the summit of the acromion, &c. We see many of these fibres, around some of the moveable articulations; much cellular texture separates them. They cannot offer any general views.

In general, the fibrous system is not as regularly organized in the ligaments as it is in the tendons, as the muscular system is in the muscles, &c. In the ligaments even with regular fasciæ, we often see fibres going in different directions, separating from the principal fascia, without any very distinct order.

FIBRO-CARTILAGINOUS SYSTEM.

THE fibro-cartilaginous system is composed of different organs which anatomists have sometimes placed among the cartilages, and sometimes among the ligaments, because they in fact partake of the nature of both. I make a system of them between the two preceding ones, a knowledge of which will facilitate the understanding of this.

ARTICLE FIRST.

OF THE FORMS OF THE FIBRO-CARTILAGINOUS SYSTEM.

WE may divide the fibro-cartilaginous organs into three classes.

The first comprehends those which are found in the ears, the alæ of the nose, the trachea, the eye-lids, &c. They are very delicate, like membranes, sometimes ar-

ranged in an uniform manner, sometimes bent in various directions. As neither their position nor functions have any thing in common, we cannot give them a denomination derived from their forms. We may designate these substances by the name of membranous fibro-cartilages. Besides it is not only in its form, but also in its nature, that this class differs from the others, as we shall see.

In the second class are ranked the inter-articular substances, which occupy the interstices of the moveable articulations, whether they are in part loose in the cavity, like those of the knee, of the lower jaw, &c. and go in different directions according to the motions, or whether, like that of the body of the vertebræ, they are fixed in a solid, though moveable manner, on the osseous surfaces. These organs are in general thicker than the preceding, very various in their form, representing commonly a kind of laminæ, sometimes perforated through the middle in the articular cavities, arranged in very thick fasciæ, and formed like the body of the vertebræ in the vertebral column. We may designate them under the name of articular fibro-cartilages.

I refer to the third class certain portions of the periosteum in which the nature of this membrane is entirely changed, becomes penetrated with gelatine and exhibits an aspect at first analogous to that of the cartilages, but in which it is easy however to distinguish the fibrous texture. These portions are found in the tendinous sheaths, in which they facilitate the sliding of the tendons, and defend the bones from their impression. They may be called the fibro-cartilages of the tendinous sheaths.

These three classes of fibro-cartilages, though very analogous, have not exactly the same structure, the same vital properties, nor the same life; so that the system they form is not as homogeneous in its different divisions, as the osseous, animal muscular systems, &c.

ARTICLE SECOND.

ORGANIZATION OF THE FIBRO-CARTILAGINOUS SYSTEM.

I. *Texture peculiar to the Organization of the Fibro-Cartilaginous System.*

The texture peculiar to the organization of the fibro-cartilaginous system is composed, as its name indicates, of a fibrous substance, more than of a true cartilage.

The fibrous substance is as the base of the organ. We distinguish this base very plainly in the fibro-cartilages of the tendinous grooves and of the articulations, in those especially of the body of the vertebræ; it is much less apparent in the membranous fibro-cartilages. Its fibres are sometimes interlaced, sometimes parallel. In general its nature is exactly the same as in the fibrous system, hard, resisting, dense and compact, hence the very great force which the organs of this system have; hence, 1st, the solidity with which the vertebræ are kept together; 2d, the difficulty of rupturing, or tearing the fibro-cartilages of the knee, the jaw, the clavicle, &c.; 3d, the resistance which that of the radius makes to the inferior luxations of this bone, luxations which in the forced pronations of this bone have great tendency to take place, and which cannot without the rupture of this fibro-cartilage. I have seen an example of a similar displacement not reduced; the fibro-cartilage was entirely gone; 4th, by bending the true cartilages they break nearly like a radish; these organs on the contrary bend in all directions, and resist the agents that stretch them; 5th, we see men imprudently raise children by their ears, the fibro-

cartilages of which easily support the weight of the whole body. I am persuaded that those of the nose would do the same. 6th. We know that in the aneurisms of the pectoral or the abdominal aorta, the bodies even of the vertebræ are much more quickly worn, and consequently resist less than the substances which unite them.

The cartilaginous portion appears to be interposed between the fibres, the interstices of which it fills. It is very evident especially in the articular fibro-cartilages and in those of the grooves; it is from it that they borrow the white colour that characterizes them, the inorganic appearance that a section of them exhibits in many places, and the elasticity which they have. Subjected to ebullition, the articular fibro-cartilages, like those of the tendinous grooves, become yellow, transparent, melt into gelatine, though with much more difficulty than the true cartilages.

As to the membranous fibro-cartilages of the ear, the nose, the trachea, the epiglottis and the eye-lids, their composition appears to be very different. The action of boiling water does not reduce them to a gelatinous state, at least in an evident manner; they remain white, soften a little, appear wholly different from a fibrous organ or the other fibro-cartilaginous organs boiled, which dissolve after becoming yellow and semi-transparent. The inspection of the ears of animals that are brought on our tables clearly proves this; I have frequently confirmed it in my experiments. I know but few of the textures in the economy that resemble this. When it has been boiled a little while, the kind of periosteum which surrounds it is detached from it; it breaks itself and cracks in many places; the rings of the trachea especially exhibit an example of this last phenomenon.

Exposed for some days to maceration, this texture, from being white, becomes of a very evident red. This colour is deeper than that which the cartilages of ossifica-

tion acquire in water; does it arise from the same causes? I know not.

When the intervertebral fibro-cartilages are macerated, their fibrous laminæ take also their reddish tinge, which I have not seen in the other articular fibro-cartilages, especially in those of the knee.

Drying makes the membranous fibro-cartilages hard and brittle; they do not take then the yellow colour of the dried tendons and aponeuroses; they have a peculiar appearance.

Subjected to this experiment, the intervertebral substances acquire a remarkable transparency, different also from that of the fibrous system, without the yellowish tinge. In the first days of their maceration, these substances, when they have been entirely detached from the vertebræ, swell, rise up and form a kind of hollow cone, the summit of which is made by the middle which especially swells, and the base by the circumference which remains nearly in the natural state.

Most of the fibro-cartilages want in general the perichondrium; this is evident in those of the tendinous grooves in which the bone on one side and the synovial membrane on the other cover the organ, in those of the articulations which this membrane surrounds on both sides, and in those of the vertebræ to which only the anterior and posterior vertebral ligaments correspond. As to the membranous fibro-cartilages, there is upon them a very distinct fibrous texture; it is thick, closely united to the peculiar texture of the organ, easily seen by maceration, which whitens it in an evident manner, and which thus makes it wholly different from the fibro-cartilaginous texture which is in the middle. By cutting a fibro-cartilage of the ear, the nose, that of the epiglottis, &c. after they have remained in water, this fact is made very clear, especially during the period in which they have the redness that I have pointed out.

The fibro-cartilaginous system appears to have nearly the same relations with the digestive juices, as the fibrous and cartilaginous systems, of the nature of which it partakes; it is altered with difficulty by those juices in a crude state. Boiling, by softening, makes it yield more to their action; it becomes then more digestible. In general, it gives an aliment less proper for nutrition, than that furnished by many other systems.

II. *Parts common to the Organization of the Fibro-Cartilaginous System.*

The common organs of the fibro-cartilages are not very conspicuous; the cellular texture is in small quantity, and so compact as hardly to be distinguished; maceration however renders it apparent.

But little blood enters their vascular system in the ordinary state; I convinced myself of this by dissecting an animal killed for the purpose by asphyxia, a disease in which the blood accumulating in the capillaries intermediate to the arteries and the veins, towards the head especially, renders these capillaries very evident; but in inflammation, which is however rare in the fibro-cartilages, they are very much injected. We can trace no nerves in them.

ARTICLE THIRD.

PROPERTIES OF THE FIBRO-CARTILAGINOUS SYSTEM

I. *Physical Properties.*

Elasticity belongs essentially to this system. This property is very evident, 1st, in the fibro-cartilages of the ears, when we bend them; 2d, in those of the nose,

when twisted in various directions; 3d, in those of the trachea, when we compress them, or after having cut them longitudinally, we separate the edges of the division, as is done in tracheotomy, when the object is the extraction of a foreign body. It performs an important use in the kind of vibration which is made in the first in the perception of sounds, in the second in the production of the voice; 4th, it is in virtue of their elasticity, that the articular fibro-cartilages serve as a kind of cushions which favour, by contracting and expanding, the motion of the osseous surfaces to which they correspond; 5th, that those of the vertebræ in particular, flattened during the day, re-act during rest, and thus make the stature in the morning something more than it is in the evening; 6th, finally in the sliding of the tendons upon their fibro-cartilages, the elasticity of these last favours the motion in an evident manner.

This elasticity of the fibro-cartilages is united to a remarkable suppleness; they bend in all directions without breaking. By the first property they resemble especially the cartilaginous system; by the second they approximate the fibrous. It is not astonishing that being intermediate to these two systems in their texture, they should be so also in their properties.

II. *Properties of Texture.*

Extensibility is very often brought into action in the fibro-cartilaginous system. I have seen a polypus that had so dilated the anterior openings and consequently the fibro-cartilages of the nostrils, that their diameter was at least treble. The external and cartilaginous extremity of the meatus auditorius often exhibits from the same cause, an analogous distension. In the various twistings of the vertebral column, the portion of the fibro-cartilages corresponding to the convexity of the curvatures, is evi-

dently elongated, whilst the opposite portion is contracted. This extensibility is moreover subjected in many cases to the same law as in the fibrous system, that is to say that it cannot be put into action but in a gradual and insensible manner.

The contractility of texture is observed when, in the cases of which I have spoken, the cause of distension disappears. Thus after the extraction of the polypus mentioned, the nostril gradually resumes its natural diameter. I have removed in a dog a tendon from its groove, by cutting it at one extremity, and drawing it by the other, so as to leave untouched and empty the sheath that contained it; this sheath and the fibro-cartilage have gradually contracted and the cavity has disappeared. In the carcinoma of the eye, in which the eye-lids were not removed, the tarsi which become much elongated with these moveable veils, gradually contract and resume their dimensions, after the extirpation of the tumour which distended them. It is necessary however to distinguish there phenomena from those which are the product of elasticity; these last are prompt and sudden; the fibro-cartilage of the ear, powerfully stretched, yields a little, and immediately goes back again; the others, on the contrary, are characterized most often by a remarkable slowness.

III. *Vital Properties.*

All the vital properties appear to be but little developed in the fibro-cartilages; there is no animal sensibility or contractility in the natural state; the first appears however in inflammation. Organic sensibility and insensible contractility are only found in the degree necessary for nutrition. There is no sensible organic contractility.

This obscurity in the vital properties, gives to all the phenomena of the life of the organs of which we are

treating, a remarkable slowness. I have observed that in making in the ears of a dog a longitudinal section, and afterwards uniting the wound by a suture, the skin, at the end of a few days, is entirely closed; but it is only at the expiration of a much longer time, that the union of the cartilage takes place below, as we can see by examining the parts after the union of the integuments. I presume that the same thing happened in the operation of tracheotomy formerly employed, in which the soft parts forming at first the cicatrix, keep in contact the cartilaginous semi-rings, which finally unite together.

It is also to this obscurity of the vital properties of the fibro-cartilages, to their want of energy, that must undoubtedly be referred the rareness of diseases of these organs. I know but few of the organic systems in the economy, which are more rarely affected than that of the fibro-cartilages of the nose, of the ears, the trachea, &c. Gangrene attacks them with difficulty; they are scarcely altered by it, whilst the soft parts which surround them are all already black. We know but little of the kind of fluid they form in their suppuration. The formation of pus appears to be even very rare in them, owing to their want of vital activity.

As these organs are hardly ever diseased, we can with difficulty know their sympathies; I am unable to cite an example of them.

ARTICLE FOURTH.

DEVELOPMENT OF THE FIBRO-CARTILAGINOUS SYSTEM.

I. *State of this System in the first age.*

In the first periods of existence, the articular fibro-cartilages are much developed, which appears to be the

effect of the size of the articulations at this period. In fact, as the extremities of the bones are larger in proportion, whilst they are cartilaginous, than when they are in the osseous state, the articulations are also proportionally larger, and the organs they contain more developed.

The fibro-cartilages of the grooves, which are found almost all, as we know, situated at the extremities of the long bones, are not, in the first age distinct from the cartilages of ossification, which then form these extremities. Confounded with them, they exhibit no line of demarcation when we cut the lines at that place. This state continues until complete ossification; then the fibro-cartilages of the grooves remain insulated like the cartilages of the osseous extremities.

The interposed gelatinous portion appears to predominate, in childhood, over the fibrous portion in the articular fibro-cartilages and in those of the grooves. It is remarkable in the intervertebral substances, in which this kind of mucilage which occupies the centre, is as to quantity in the inverse ratio of the age, and in which the fibres are also more developed. On the pubis, the whole is almost homogeneous in the fœtus; the transverse fibres do not become very apparent till a more advanced age. The articulations of the knee, the jaw, &c. have in their fibro-cartilages, the same arrangement. Ebullition extracts from them then a much greater quantity of gelatine; they have more the smooth appearance of the cartilages.

The membranous fibro-cartilages are in general developed early, those of the ear, the eyes and the nose especially. We see them very evident in the fœtus. I have observed in two acephalous infants, that, like all the other parts of the face, they were of a remarkable size, and much greater than that of the ordinary state. Besides, the whole fibro-cartilaginous system is, in the fœtus, extremely soft, supple and unresisting.

II. *State of the Fibro-Cartilaginous System in the after ages.*

This system becomes stronger as we advance in age; in old age, it becomes hard and yields with difficulty from the peculiar nature of its nutritive substances. It is to this circumstance that must be attributed, 1st, the stiffness and inflexibility of the vertebral column, whose fibro-cartilages keep all the pieces in a kind of immobility; 2d, a part of the difficulties which an old person experiences in hearing sounds, the concha not being able to vibrate and reflect them as well as before; 3d, the less susceptibility of his nostrils to dilate, the fibro-cartilages yielding less to the muscular effort, which is besides also less; 4th, the difficulties of the sliding of the tendons, their grooves being much less supple.

The fibro-cartilages have in general much less tendency to ossify in old age, than the cartilages properly so called. I never saw this phenomenon in the membranous ones; perhaps it arises from their peculiar texture, and even the difference of the principles which go to their composition, and from the small quantity of gelatine that enters into them. Among the articular, there are scarcely any but those of the vertebræ, which are sometimes entered by the phosphate of lime; this is however rare. Those of the grooves are like the cartilages of the moveable articulations, they constantly keep their nature; only in extreme old age, their thickness appears to diminish a little by the ossification of their laminæ which correspond to the bone, which besides is not very evident.

MUSCULAR SYSTEM OF ANIMAL LIFE.

THE general muscular system very evidently forms two great divisions, differing essentially from each other, by the vital forces that animate them, by their external forms, by their mode of organization, and especially by the parts they perform, the one in animal life, and the other in organic. We shall not then consider them together. Let us begin by the examination of the muscles of animal life; these are spread out in great number in the human body. No system as a whole, is of more considerable size; no one occupies more space in the economy. Besides the numerous regions that the muscles fill, they are generally spread out under the skin, and partake, as it were, of the functions of this organ, protect like it the subjacent parts, like it bear with impunity the action of external bodies, and can even be divided in a more or less considerable extent, without the general functions of life suffering from it; which renders them very fit to defend the deep-seated organs, whose lesion would be very injurious.

ARTICLE FIRST.

Of the Forms of the Muscular System of Animal Life.

FROM their external forms, the muscles may be divided, like the bones, into long, broad and short. Their

arrangement varies according to these three general forms.

I. *Forms of the Long Muscles.*

The long muscles occupy in general the limbs, to the conformation of which theirs is accommodated. Separated from the skin by the aponeuroses, from the bone by the periosteum, they are situated in a sort of fibrous gutter, which retains them powerfully, and in which they are arranged in layers more or less numerous, the deep ones are confined in their place by the superficial ones, which, in their turn, have the aponeuroses to support them. These last are very long; they commonly belong to the motions of three or four bones and even more, examples of which we have in the sartorius, the semi-tendinosus and membranosus, the biceps, the flexors and the extensors. As they become deeper, they are also shorter and generally destined to the motions of two bones only, as the adductors, the pectineus, &c. are a proof.

Cellular layers separate them; they are loose where great motions take place, more compact where these motions are less, very thick where vessels and nerves go between the muscular fasciculi. Often spaces more or less considerable, filled with cellular texture, separate these fasciculi from each other. We divide the long muscles into simple and compound. They are simple when a single fasciculus forms them, compound when they arise from the union of many. These fasciculi are found then in two different manners; sometimes in fact its division is at the top of the muscle, as we see in the brachial and femoral biceps; sometimes it is at the inferior part, at the most moveable side that this division is met with, as in the flexor and extensor muscles of the leg and the fore-arm.

The long muscles often separate from each other, are sometimes held together by means of aponeuroses, which confound a more or less considerable portion of two, three and even four of these neighbouring organs. The origin of the muscles of the internal and external tuberosities of the humerus exhibits this arrangement, whence results an essential advantage in the general motions of the limb. Then in fact the contraction of each muscle serves, both to cause a motion below in the moveable part to which it is attached, and to strengthen above the fixed point of the neighbouring muscles which contract at the same time with it.

Every long muscle is in general thicker in its middle than at its extremities, a form which arises from the manner of the insertion of the fleshy fibres, which arising above and terminating below, some successively below others, are so much the less numerous as we approach nearer each extremity, whilst in the middle they are all found in juxta-position. The anterior rectus, the long supinator, the external radial muscles, &c. have manifestly this arrangement.

There is a particular kind of long muscles, which has no analogy but in external appearance with that of the muscles of the limbs. They are those that are embedded in front and especially behind the spine. Though they appear simple at first view, these muscles have as many distinct fasciculi as there are vertebræ. The transversalis colli, the sacro-lumbalis, the longus colli, &c. represent very well an elongated fasciculus like the sartorius, the anterior rectus of the thigh, &c.; but the structure of this fasciculus has nothing in common with that of these muscles; it is a series of small fasciculi, which have each their distinct origin and termination, and which appear to be confounded into one muscle only because they are in juxta-position.

II. *Forms of the Broad Muscles.*

The broad muscles occupy in general the parietes of the cavities of the animal economy, those of the thorax and abdomen especially. They form in part, these parietes, defend the internal organs, and at the same time by their motions assist their functions.

Their thickness is not great; most of them appear like muscular membranes, sometimes arranged in layers, as in the abdomen, sometimes covering the long muscles, as on the back; they are in the first case, much more extensive superficially than deeper seated.

Whenever a broad muscle arises and terminates on one of the great cavities, it preserves everywhere nearly its breadth, because it has a large surface for its insertion. But if from a cavity it goes to a long bone, or to a small apophysis, then its fibres gradually approximate; it loses its breadth, increases in thickness, and terminates in an angle which is succeeded by a tendon, which concentrates into a very small space fibres widely scattered on the side of the cavity. The great dorsal and pectoral muscles present us an example of this arrangement, which is met with also in the iliacus, in the glutæi medius and minimus. The broad muscles of the pectoral cavity have a peculiar arrangement which the ribs require; their origin takes place by serrated points fixed to these bones, and separated by spaces between them.

The broad muscles are most often simple; many rarely unite to form compound ones. Different cellular layers separate them, like the long muscles; but they are hardly ever like them covered by aponeuroses; the greatest number is merely subjacent to the integuments; the reason is that their form naturally protects them from these displacements, of which we have spoken in the article on aponeuroses, and which, without these membranes, would be so frequent in the long muscles. I do not know that

the cramp has ever been observed in those of which we are treating. When the abdominal muscles are laid bare by incisions made through the integuments of a living animal, I have observed, that in contracting, the bulk of each preserves the same place.

III. *Forms of the Short Muscles.*

The short muscles are those in which the three dimensions are nearly equal, having a thickness in proportion to their width and their length. They are found in general in the places, where is required on the one hand much power, and on the other small extent of motion; thus around the temporo-maxillary articulation the masseter and pterygoids, around the ischio-femoral the quadratus the gemini the obturators, &c. around the scapulo-humeral the supra-spinalis and the teres minor, in the hand the muscles of the palmar eminences, in the foot various fleshy fasciculi, in the vertebral column the interspinal, in the head the small and great anterior, posterior and lateral recti, exhibit more or less regularly the form of which we are treating, and answer the double object that I have indicated, on the one hand by the very considerable number and on the other by the shortness of their fibres.

The short muscles are, more often than the broad, united to each other, either in their origin or termination, as we see in the foot and the hand. Sometimes they are of a triangular form, as in these two parts; sometimes they approach to the form of a cube, of which there is an example in the masseter and pterygoid muscles. In general they are rarely covered by aponeuroses, undoubtedly because the shortness of their fibres prevents them from being liable in a great degree to considerable displacements.

Besides, the division of the muscles into long, broad and short, is, like that of the bones, subject to an infinite

number of modifications. In fact many of these organs have mixed characters; thus the sub-scapularis and the infra-spinalis have a form intermediate to the broad and short one; thus the cruræus, the gemelli of the leg, &c. cannot be considered precisely long or broad muscles. Nature varies, according to the functions of the organs, the conformation of the agents of their motions, and we can only establish approximations in our anatomical divisions.

ARTICLE SECOND.

ORGANIZATION OF THE MUSCULAR SYSTEM OF ANIMAL LIFE.

The part peculiar to a muscle is what is commonly called the muscular fibre; the vessels, the nerves, the exhalants, the absorbents and the cellular texture, which is very abundant around this fibre, form its common parts.

I. *Texture peculiar to the Organization of the Muscular System of Animal Life.*

The muscular fibre is red, soft, of an uniform size in the great and small muscles, sometimes disposed in very evident fasciculi and separated from each other by remarkable grooves, as in the gluteus maximus, the deltoid, &c. sometimes more equally in juxta-position, as in most of the broad muscles, always united to many others of the same nature like it, easily by this union distinguished by the naked eye, but eluding microscopic researches when

we wish to examine it in a separate manner, so great is its tenuity. Notwithstanding this extreme tenuity, an infinite number of researches have been made during the last age, to determine with precision the size of this fibre. On this point may be read the result of the labours of Leuwenhoek, Muysk, &c. I shall not give here this result, because science can draw nothing from it, and because we cannot rely upon its accuracy ; of what importance moreover is the precise size of the muscular fibre ? its knowledge would add nothing to our physiological views upon the motion of the muscles.

Every muscular fibre runs its course without bifurcating or dividing in any manner, though many have thought otherwise ; it is found only in juxta-position to those which are near it, and not intermixed, as often happens in the fibrous system ; an arrangement that was rendered necessary by the insulated motions it performs ; for the general contraction of a muscle is the union of many partial contractions, wholly distinct and independent of each other.

The length of the fleshy fibres varies very much. If we examine in general the mass which they form by their union, we observe that this mass has sometimes much greater extent than the tendinous portion of the muscle, as the biceps, the coraco-brachialis, the rectus internus femoris, &c. ; that sometimes its length is much less as in the small plantar and palmar muscles, &c. ; and that sometimes it is about equal, as in the external radial, &c. If from the examination of the fleshy mass, we pass to that of the separate fibres that compose it, we see that the length of the first is rarely the same as that of the second. There are hardly any but the sartorius and some analogous muscles, whose fibres run the whole extent of the fleshy mass ; in almost all the others, they are found obliquely arranged between two aponeuroses, or between a tendon and an aponeurosis ; so that though each of them

may be very short, as a whole they are very long, as we observe in the anterior rectus of the thigh, the semi-membranosus, &c. This arrangement may also arise from various tendinous intersections, which cut at different distances the length of the fibres. In general, the muscles which owe their length to long fibres, have great extent and very little power of motion ; whilst those with short fibres, but multiplied so as to give great length as a whole, are remarkable for an opposite character. And this is the reason : all the fibres being equally large, whatever may be their length, have the same degree of force ; it is evident then that this force considered in a muscle as a whole, is measured by the number of its fibres. On the other hand, the longer a fibre is, the more it shortens in its contraction ; then by contracting, a muscle brings its attachments so much the nearer in proportion as its fibres are longer.

All the fibres of the voluntary muscles are straight, those of the sphincters excepted. They are either parallel as in the rhomboids, or obliquely situated in relation to each other, as in the great pectoral. Sometimes in the same muscle many sets cross each other in different directions, as we see in the masseter ; but this crossing is wholly different from that of the involuntary muscles in which there is more crossing of fibres, whilst here we see only fasciculi in different directions, in juxta-position to each other.

I shall not speak here of the cylindrical form according to some, and the globular one according to others, of the fleshy fibre : inspection teaches us nothing upon this point ; how then can we make that an object of research and give an opinion upon it, which has no real foundation ? Let us say thus much of the intimate nature of this fibre, upon which so much has been written. It is unknown to us, and all that has been said upon its continuity with the vascular and nervous extremities, upon its pre-

tended cavity, upon the marrow, which according to some filled it, &c. is only a collection of vague ideas, which nothing positive confirms, and to which a methodical mind would not attend. Let us begin to study nature where she begins to come under our senses. I would compare the anatomical researches upon the intimate structure of the organs, to the physiological researches upon the first causes of the functions. In both we are without guides, without precise and accurate data; why then give ourselves up to them?

All that we can know upon the nature of the muscular fibre, is that it is peculiar, that it is not the same as that of the nerves, nor as that of the vessels, nor as that of the tendons or the cellular texture; for where there is identity of nature, there ought to be identity of vital properties and of texture. Now we shall see that all these systems differ essentially from each other in this point of view; there can be between them no analogy in relation to their nature, whence the properties are always derived.

The muscular texture is remarkable for its softness and small degree of resistance. It is by this that it is essentially different from the fibrous texture. It breaks with ease in the dead body. In the living, this rupture is rare, because the contraction which exists in all the violent efforts, gives it a density, by which it gains an enormous increase of resistance, but which it loses when it is no longer in a state of contraction. There are however examples of the rupture of muscles; it is principally in the rectus abdominis and quadratus lumborum that they take place. I have seen one in this last. Observe that this muscle and all those placed between the ribs and the pelvis, are much disposed, from their situation, to these ruptures. In fact, when the pelvis and the thorax are carried in an opposite direction, these muscles are so much the more violently stretched, as in these motions all the

superior part of the body forms with the thorax, a great lever, which is moved in an opposite direction to another great lever, which is formed by the pelvis and all the inferior parts; now from their length, these levers are capable of receiving a very great motion, of communicating it consequently to the abdominal muscles which are stretched between the two, and which serve to unite them. Hence how in a violent inclination to the right, the quadratus of the left side can be torn, &c. Observe that but few of the muscles in the economy are found between two levers so great, consequently are capable of being so much distended, and especially of being so with a force greater than that of their contraction; for every muscular rupture supposes the excess of the external motion, which distends, over that of the fleshy fibres which contract to oppose this distension. If the external efforts were concentrated upon a single muscle, they would be able more often to overcome the resistance; but almost always many partake of the effort to support and the resistance to oppose.

Composition of the Muscular Texture.

The muscular texture has been with chemists, a more particular object of research than most of the other organized textures. They have examined it under all its relations. I refer to their works, to that of Fourcroy especially, for all which is not strictly relative to the nature of this texture, for all which considers consequences not applicable to physiology, which we can deduce from the knowledge of the principles that enter into its composition.

Exposed to the action of the air, the muscular texture is affected in two ways. 1st. It dries, if cut into thin slices, admitting of the evaporation of the fluids it contains. Then its appearance is of a dull brown; its fibres contract, it becomes thinner, hard and brittle. If re-

plunged into water within some days, even fifteen or thirty after its drying, it resumes its primitive softness and form, and has a less deep coloured tinge. The water that has been used for this softening is more or less fetid, and similar to that of macerations. 2d. Exposed in too great a mass to the air, the muscular texture does not dry, but becomes putrid. Thus in making anatomical preparations by drying, care should be taken to lessen the thickness of the fleshy parts, or to arrange them so that the air can penetrate them everywhere. Putrefaction is inevitable if the air is moist, if the evaporation of the fluids is not quick enough to produce drying. When it becomes putrid, the muscle assumes a green, livid colour; it exhales an offensive odour. Under the influence of the same circumstances it becomes putrid much quicker than the fibrous, the cartilaginous and the fibro-cartilaginous systems. The odour that it exhales then is also very different from that of these systems; a phosphoric light often escapes from it. A mass of putridity, in which all the fibres have almost disappeared, takes the place of the muscle, when putrefaction is advanced. This mass of putridity gradually evaporates in part, and there remains a dark brown residue, which dries and becomes hard and brittle, nearly like the muscle dried in the ordinary state, though the appearance however may be very different.

Exposed to the action of water, the muscle undergoes different phenomena, according as it is hot or cold. Cold water takes from it at first its red colour, of which it appears to dissolve the principle. To effect quickly this phenomenon, it is necessary to expose the flesh, at first in thin layers, to the action of water that is often changed, by placing a muscle for example under a fountain, in the current of a river, or what is much better, by frequently expressing the water it imbibes; for if we keep it in a vessel, its exterior only whitens a little, and the interior preserves its colour. Water which has been used to

wash a muscle, looks like blood spread out in this fluid; it contains the colouring matter, a little of the extractive substance, gelatine, &c. I believe that of all the organs the muscle is that from which we remove most easily its colour by artificial means. Ought we to be astonished after this, if nature varies so evidently and so frequently this colour by the phenomena of nutrition, as we soon shall have occasion to remark? Kept in water at a moderate temperature, the muscular texture remains for a long time without softening; it finally does, and changes layer by layer into a kind of putridity very different however from that which is formed in the open air, as I have frequently observed in macerating the muscles in a cellar, the temperature of which is uniform. At other times, instead of putrefying thus, the muscle is changed, as Fourcroy has remarked, into a substance like spermaceti; then its fibre is hard and solid. But all the muscles when kept in water by no means exhibit this phenomenon. When it does take place, very often a kind of reddish product, scattered here and there on the surface of the muscle, and which is an evident effect of decomposition, announces and afterwards accompanies this state, without which also, it often takes place. Maceration in dissecting rooms frequently exhibits this phenomenon.

When we have taken from the muscles their colouring substance by repeated washings, there remains a white fibrous texture, from which we can still extract albumen by ebullition, which rises in scum, gelatine by suffering it to grow cold, extractive matter which has a deep colour, by letting it settle, and some phosphoric salts. When all these substances have disappeared, the residue of the muscle is a fibrous substance, of a greyish colour, insoluble in warm water, soluble in the weak acids, giving out much azote from the action of the nitric acid, and presenting all the characters of the fibrin of the blood. It appears, as Fourcroy has remarked, that this substance is truly the

nutritive substance of the muscle, that which, continually exhaled and absorbed, contributes to its nutritive phenomena more than all the others ; it constitutes the essence of the muscle, it especially characterizes it, as the phosphate of lime is the nutritive characteristic matter of the bones. Is this substance formed in the blood and carried from it to the muscle, or is it formed in the muscle by nutrition, and thence carried to the blood ? I know not. Whichever may be the case, it appears to experience very great varieties in its exhalation and absorption. The state of laxity, of cohesion, the thousand various appearances of the muscular texture, appear to belong in part to these varieties of proportion. Thus the phosphate of lime or gelatine, diminished by nutrition, give to the bones softness or brittleness.

It is in this fibrous and essential portion of the muscle, that particularly resides the faculty of crisping by the action of caloric, whether by plunging a muscle into boiling water, or exposing it to the fire ; for this crisping is as evident in the muscle deprived of its colouring matter, its gelatine, its albumen, and even a portion of its extractive substance as in the ordinary muscle. There is in general a constant relation between the quantity of this fibrous substance contained in the muscles, and the quantity that the blood contains of it. In the strong, vigorous, sanguineous temperaments, as they are called, the muscles are thick and much more fibrous. In all the slow cachexiæ in which the blood is impoverished, the pulse small and feeble and in which muscular nutrition has had time to share but little of the fibrin of the blood, the muscles are small, weak, soft, &c. In general, the muscles and the blood are always in constant relation, whilst other systems often predominate and whilst this fluid seems to be in less quantity in the economy.

Exposed for a long time to ebullition, as in common boiled meat, the muscular texture, still united to the adja-

cent organs, and to its common parts, gives, 1st, an albuminous scum which appears to arise more from the lymph of the cells than from the muscle itself; 2d, many fatty drops coming also especially from the cellular texture, almost foreign consequently to the texture of the muscle, and which swim on its surface; 3d, gelatine formed especially by the aponeurotic intersections; 4th, an extractive substance which colours in part the water in which it is boiled, gives it a peculiar taste and remains in part adherent to the flesh to which it communicates a deep tinge wholly different from that of raw flesh, a tinge which arises also from the colouring matter of the muscle, and which moreover changes, when the liquor cools, into a less deep and even a whitish tinge; 5th, various salts which contribute much to the taste of the liquor, and the nature of which chemists have ascertained. These are the natural phenomena of the ebullition of the muscle.

The more extensive analysis of boiled flesh is not my province; but what ought not to escape us here, are the phenomena of which the fibre is the seat, whilst the preceding products are extracted, whether from it, or the surrounding textures. These phenomena can be referred to three periods. 1st. When the water is only tepid, and even a little above the temperature of the body, it leaves the muscular texture in the same state, or softens it a little. 2d. When it approaches ebullition and begins to be covered with an albuminous scum, the texture crisps, thickens and contracts and gives to the muscle a density much greater than what is natural to it, and augments considerably its resistance. I have observed that in this state the muscles bear much greater weights than in a natural state. They approximate, if we may so say, that remarkable density which characterizes them when they contract in the living body, and which so powerfully opposes their rupture. This condensation of the muscular texture, which is prompt and sudden, increases till the

period of ebullition, when it is at its greatest height; it continues only for a certain time. 3d. Gradually it diminishes, the fibres soften, and are more easily torn than in their natural state. This softening, the reverse of the hardening that precedes, is produced slowly and by degrees. When arrived to a certain degree, the meat is rendered fit for the table. Observe that then the muscle has not returned to the state in which it was found before the hardening; among other phenomena which distinguish it, the following is an essential one; it has lost the power of crisping, of acquiring the horny hardness, from the action of the concentrated acids, from alkohol or from caloric. In general it becomes putrid more slowly. Its putrefaction does not give the same odour. We know how much its taste differs. The principles it has lost are undoubtedly one of the great causes of these differences.

When a muscle is exposed to an open fire, as in the roasting of meat, the albumen is condensed, the gelatine melts, the fibrin filled with juices softens, the extractive matter flows in part with the gelatine and the salts held in solution; it is this that forms the gravy, which is, as we know, very different from melted fat. The exterior of the meat remains more dense than the interior; it is coloured by the extractive substance. The interior loses in part its natural colour; its consistence, its taste and its composition even change entirely. The fibres, as in ebullition, lose the power of contracting and of crisping from the action of strong stimuli and especially that of fire.

No part in the animal economy is more easily altered by the digestive juices than the muscles. Almost all stomachs can bear boiled meat, whilst many reject other organs when cooked. Carnivorous animals seize upon the muscles of their prey in preference to the pectoral and gastric viscera. Muscular flesh is with most people the most common aliment, that with which they are never

disgusted; it appears to be the most nourishing of all those, which are afforded by the different textures of animals; is it, as it has been said, because it contains the most azote? Whatever may be the reason, the general part which the muscular system takes in the digestion of all carnivorous animals, of man especially, is remarkable. Yet all the parts of this system do not appear to be equally agreeable to the taste of animals. It is, for example, a singular fact, that those bodies which are brought to our dissecting rooms, and which have been attacked by rats, are found almost always exclusively gnawed in the muscles of the face.

Observe in regard to the use of the muscles in digestion, that it is the portion of the fibrous system which adheres to them, and forms, as it were, a part of them, I refer to the tendons, which is the most easily altered by maceration, by ebullition and by the digestive juices. Observe also that the great mass which the muscles form in the body of all animals, of which they are more than one third, presents to the carnivorous species ample materials for their nutrition; thus nature, by multiplying these organs for the wants of the individual which they move, seems to multiply them also for those of the individuals which he is one day to nourish. In forming them in each species, it labours for other species as well as for this. Who knows if this general design, which observation finds in the series of all animals, be not the cause of this remarkable predominance which the muscles have over the other systems? Who knows, if nature would not have diminished the powers of the animal mechanism which are so numerous and so complicated in comparison with those of artificial machines, who knows if she would not have simplified the means and given the same results, if the motions of the animals had been the only object of the formation of the muscles?

The sex has great influence on the quality of the flesh of animals. I do not believe that any thing precise is known as to the nature of the influence which the genital parts exert upon it; but the following are remarkable facts upon this subject. The muscles of males are stronger and better nourished, have more taste, resist boiling for a longer time, are firmer, &c. Boiling water on the contrary alters quicker the texture of females; it is more tender and gives to the liquor a less strong taste. In the season of sexual intercourse, the muscular system of the first has a peculiar odour, which often renders it disagreeable even to the taste. It is an observation that is easily made in quadrupeds, birds and fishes that are brought to our tables. Without having as strong an odour, the flesh of the second becomes at this period soft, flaccid and but little savoury.

II. *Parts common to the Organization of the Muscular System of Animal Life.*

Cellular Texture.

The cellular texture is very abundant in the muscular system; I know of no system that has a greater proportion of it. This texture forms a very evident covering around each muscle. This covering is most commonly loose, filled with fat, easily distended with air in emphysema and serum in anasarca. At other times it is more dense, compact and really arranged like a membrane. Such, for example, is the case with that which covers the great oblique muscle of the abdomen, and the dissection of which on this account, students at first find very difficult. The other abdominal muscles, the trapezius, the serratus major and the great dorsal exhibit also this arrangement. We might say that in this way nature compensated for the aponeuroses, which are wanting on the broad muscles of the trunk. Besides, this covering has

only a membranous appearance; it has nothing of its organization, it disappears in the infiltration in which all the true membranes remain.

Besides this general covering of the muscle, each fasciculus has a less covering, each fibre a still less one, and each smaller one a real though almost insensible sheath. We can then represent the cellular texture of the muscles as forming a series of coverings successively decreasing. These coverings favour the motion of the fibres which they separate, either by the serum of the cells, or by the fat they contain, both fluids, by lubricating, allow them to slip more easily upon each other. Frequently between these fibres, the cellular texture appears to form a kind of cross pieces which go at right angles. We see this arrangement especially in the proper extensor of the great toe, and in the common extensor, the fleshy fasciculi of which are broad and delicate when distended. In most of the thick muscles nothing similar is observed.

The quantity of intermuscular cellular texture is remarkably variable. In general, in all the broad muscles and in all the large, long muscles, it is very abundant. It is less in proportion between the fibres of those of the vertebral canals. Back of the neck, the splenii, complexi, &c. have less of it than many others, especially in the spaces that separate them.

Sometimes very considerable cellular elongations are found in the middle of the muscles, and seem to divide them into two; such is that which separates the clavicular portion of the great pectoral; this has even sometimes embarrassed anatomists as to the division of these organs.

The cellular texture in general fixes the muscles in their position; the art of dissection proves it. The effusions of pus which often perform the office of the scalpel, render also very evident this use, which does not prevent the motion in all directions, that the great extensibility

of the cellular texture allows. The cellular texture not only fixes the muscles to each other, but it also attaches each of their fibres to neighbouring ones; it flattens them when they contract, and elongates them when they are distended; if they are deprived of it their motions become irregular and uncertain. I have many times separated with a scalpel a muscle laid bare in a living animal, into many small fasciculi; in afterwards making this muscle contract by the irritation of the medulla, by means of a stilet introduced into its canal, I have observed in an evident manner this irregularity of motion. Cut longitudinally a muscle of an extremity from its superior tendon to its inferior, so as to divide it into two or three entirely distinct portions, irritate afterwards one of these portions, the other or the two others will remain almost always at rest, whilst a single irritated fibre in a sound muscle, puts in motion the whole of that muscle. The section of the vessels and the nerves has no doubt a little influence upon this phenomenon; but that of the cellular texture certainly contributes to it also.

In dropsical subjects, the serum of the intermuscular texture is often reddish; this phenomenon is owing to the action of this serum after death upon the colouring substance. I believe that this can take place during life only with great difficulty. The fat sometimes abounds in this texture, to such a degree that the fleshy fibres disappear and the fat only is visible; but oftentimes also the yellow appearance of the muscular fibres, which is produced by the absence of the colouring substance, is taken for this fatty state of the muscles. I have seen the first state but rarely; the second is extremely frequent; we are sometimes deceived at first view. But ebullition and combustion easily prove, that the fat is wholly foreign to this want of colour of the muscles examined in this state.

Blood Vessels.

The arteries of the muscles are very apparent; they come from the neighbouring trunks, penetrate the whole circumference of the organ, more however towards its middle, than towards its extremities. They run at first between the principal fasiculi, then divide and their divisions go between the secondary fasciculi, subdivide and wind between the fibres, and finally become capillaries and accompany the small fibres, in which they deposit by the exhalant system the nutritive matter. There are but few organs, which have, in proportion to their size, more blood than the muscles.

The blood is essentially necessary to support their excitability, as we shall see; it is that which colours the muscular texture, but not, as it at first seems, by circulating in its texture. The circulating or free portion contributes but little to it. It is the portion combined with the muscular texture, that which contributes to its nutrition, that gives it its colour; the following are proofs of it: 1st. The fibres of the intestines are as much or more penetrated with the circulating blood, than those of the muscles of animal life, and yet their texture is evidently whitish, where these vessels are not found. 2d. Many animals with red and cold blood, frogs in particular, have muscles almost white, and yet many red vessels run through this white texture. 3d. I have observed that in animals destroyed by asphyxia, the colouring substance does not change colour, no doubt because it is slowly combined with the muscle by nutrition; that on the contrary, if we cut a muscle of these animals in the last moments of life, whilst the venous blood still circulates in the arterial system, this blood flows out by black jets from the muscular arteries, the muscular texture itself remaining red. This curious experiment, which I have noticed in another work, is made by producing asphyxia

in an animal by compressing the trachea, or by intercepting the air in any other way in this tube, whilst we examine the system of the muscles. When a muscle has been exposed for some time to the contact of the air, to that of oxygen especially, its red colour becomes evidently more brilliant.

The muscular vessels permit under certain circumstances the escape of the blood they contain; hence different kinds of remarkable hemorrhages, especially in scorbutic patients, sometimes in putrid fevers, rarely or never in those diseases that are characterized by an increase of vitality. Infiltrated with blood in preternatural hemorrhages, particularly in false aneurisms, the muscles lose in part their motion; this happens also in contusions, in which similar infiltrations are observed.

The veins everywhere follow the arteries in the muscles; they have the same distributions, and receive from the contractions of these organs an essential assistance to their action. The throw of blood is more powerful when the patient we have bled contracts his muscles, than when he relaxes them; the fluid is as it were expressed, as from a wet sponge which is squeezed. The arterial circulation does not exhibit this phenomenon. I have observed that if we open the artery of the foot of an animal, and by the irritation of the nerves, make the muscles of the leg and thigh, through which this artery passes before reaching the foot, contract powerfully, the throw of blood is not stronger than during the relaxation.

I have many times injected the veins of the muscles of animal life with ease, from the trunks towards the branches, which makes me believe, notwithstanding what Haller has said, that in these organs, as in the heart, the valves are less numerous than in many others. No doubt the assistance the veins derive from their surrounding organs supplies the place of these folds, or rather renders them useless, the weight of the column of blood not

making a great effort against the venous parietes. The varices of the muscular veins are, as we know, extremely rare. These veins are of two orders; one accompanies the arteries and follows the same course, the others are spread superficially on the surface of the organ, without having corresponding arteries.

There are absorbents and exhalants in the muscles; but we can with difficulty trace the first, and the second cannot be perceived.

Nerves.

Almost all the nerves of the muscles of animal life come from the brain; the ganglions furnish a few of them; when this happens, as in the neck, the pelvis, &c. besides the filaments coming from these nervous centres, there are always filaments of cerebral nerves; without this, these muscles would be involuntary. Few organs receive more nerves in proportion to their size than the muscles. In general the extensors appear to have rather fewer than the flexors; but the difference is trifling. It is true that all the great nervous trunks are in the direction of flexion, that in that of extension there are only branches, as we see in the posterior part of the arm, of the fore-arm, the vertebral column, &c. It is true also that this remark is likewise applicable to the existence of the vessels, which are larger and more numerous in the first than in the second direction; but this greater number of vessels and nerves arises from this, that there are many more flexors than extensors, that the first are stronger and have more numerous fibres; so that each of these fibres hardly receives more nervous or vascular filaments in one kind of muscles than in the other. I think that there is but little foundation for what has been said upon the difference of the strength of the fibres of the flexors and of the extensors, upon the predominance of the first, &c. If these are superior, it is either because they are

more numerous, as in the foot, the hand, &c. or more advantageously arranged, as in the trunk on which the abdominal muscles act very far from the point of attachment to bend the spine, whilst to extend it, the dorsal muscles exert their action immediately at the side of this point of attachment, as also in the neck, where the muscles that draw down the lower jaw and head when this bone is fixed, are much further from the occipital condyles, than the muscles which produce extension. Whatever may be the cause of the superiority of the flexors, the fact cannot be doubted. 1st. In hysterical convulsions, in those of infants, in all the spasmodic motions in which the will has no part, the contractions take place much more in the direction of flexion than in that of extension. 2d. In old people the flexors finally become superior to the extensors; for example, the fingers and toes are almost uniformly bent. 3d. In all the motions, the power is always on the side of flexion.

The nerves enter the muscles of the extremities at a very acute angle, because the nervous trunks are in the natural direction of these organs. In the trunk, on the contrary, the nerves going from the spine, the cervical especially, enter their muscles at almost a right angle or one less evidently acute; this circumstance is of no importance. Each branch in the fleshy fibres, is at first divided and then sub-divided in their interstices, and afterwards lost in their texture. Does each fibre receive a small nervous filament? We should be led to believe so from this observation, that the principal branch being irritated, all the fibres are put into action, no one remains inert. But on the other hand, if we irritate one of them, all move also, which is certainly a sympathetic phenomenon or one arising from the communication of the cells.

Are the nerves deprived of their cellular coverings, and do they become pulpy when they enter the muscles? Dissection has shewn me nothing like it.

ARTICLE THIRD.

PROPERTIES OF THE MUSCULAR SYSTEM OF ANIMAL LIFE.

There are but few systems in the economy in which the vital properties and those of texture are found in so great and evident a degree as in this. It is from the muscles that examples must be selected to give a precise and accurate idea of these properties. The physical properties on the contrary are slightly marked in them; a remarkable softness characterizes them; there is no elastic power in their texture; there is but very little resistance from this texture after death; it is from vitality that it derives the power that characterizes it in its functions.

I. *Properties of Texture. Extensibility.*

Extensibility is manifested in the animal muscular system under many circumstances. The different motions of our parts render this property evident. Such is in fact the arrangement of the muscular system, that one of its portions cannot contract, without the distension of another. The thigh being strongly bent, the semi-membranosus, the semi-tendinosus and the biceps are elongated. The arm being carried out, the great pectoral is extended, being raised, the great dorsal and the teres major are stretched. All the great flexions bring into action this property in the extensors; all the extensions render it evident in the flexors. A muscle which is stretched by its antagonist is in a state purely passive; it is as it were for a moment abandoned by its contractility, or rather it possesses it, without its being brought into action; it is

made to obey the motion that is communicated to it. Observe that in these cases, the distension is confined to the fleshy portion, and the tendon has no connexion with it; it remains the same, whatever may be the distance of the points of attachment, for these points are nearer or more remote in the different extensions to which the muscles are exposed; the longest muscles yield the easiest. The sartorius, the posterior muscles of the thigh, &c. exhibit this phenomenon in an evident manner; as their position is accommodated to it. In general all the muscles remarkable for their length are superficial, and go most commonly to two articulations, sometimes even to three or four, as in the limbs. Now the number of these articulations renders the space comprised between the two points of attachment susceptible of very great variations, which the great extensibility of these muscles allows. It may be understood from what has been said above, that it is to the length of the fleshy fibres and to the whole length of the muscle, that its degree of extensibility is to be referred. Those in which many aponeuroses are intermixed, and which derive in part from these membranes or from tendons their length, possess less of this property. Hence why, in the same motions, muscles of the same total length become more or less short, more or less elongated in their fleshy portion. Observe however that when on the one hand the tendinous portion predominates much, and on the other that it is very delicate, it yields a little, as we see in the small plantar and palmar muscles.

If from the natural state we pass to the morbid, we see the muscular extensibility manifested in a much more evident degree. In the face, the air accumulated in the mouth, swells it by elongating the buccinators; the various tumours of this cavity, as the fungous and sarcomatous ones, often distend the small facial muscles in a manner which would astonish us, if we considered the naturally

small extent of these muscles which are trebled and even quadrupled. The muscles of the eye-lids and the eye in the large carcinomas of that organ, those of the anterior part of the neck in the great swellings of the thyroid gland, the great pectoral in large aneurisms or in other tumours of the axilla, the abdominal muscles in pregnancy, in dropsy, in the various tumours of the abdomen, &c. the broad and superficial muscles of the back from wens that are under them, present us these phenomena of distension in a remarkable manner. The muscles of the extremities are less subject to them, because on the one hand fewer causes develop tumours beneath them, and because on the other the aponeuroses do not yield so easily to these phenomena.

Contractility of Texture.

The contractility of texture is carried to the highest point in the muscles. These organs have a continual tendency to contraction, especially when by being elongated, they have surpassed their natural size. This tendency is independent of the action of the nerves, and of the irritable property of the muscular texture. It is influenced by life, but it is not entirely dependent on it; it depends essentially on the structure of the muscles. The remarkable phenomenon of the antagonist muscles results from it. The following is this phenomenon.

Each moveable point of the animal frame is always between two opposite muscular forces, between those of flexion and extension, of elevation and depression, of adduction and abduction, of rotation without and rotation within, &c. This opposition is a condition essential to the motions; for in order to perform one of them, it is necessary that the moveable point should be in the opposite motion; in order to bend, it is necessary that it should be first extended, and reciprocally. The two opposite positions which a moveable part takes, are for it

alternately the point of departure and the point of arrival; the two extremes of these positions are the two limits between which it can move. Now between these limits there is a middle point; it is the point of rest of the moveable part; when it is found there, the muscles are in their natural state; when it passes it, some are extended, others are contracted, and such is their arrangement, that the contraction and extension which take place in an opposite direction, are exactly in direct ratio. Hence, in the reciprocal influence that the muscles exert upon each other, they are alternately active and passive, power and resistance, organs moved and organs which move. The effect of every muscle which contracts is not then only to act upon the bone in which it is inserted, but also upon the opposite muscle. Between two muscles thus opposed, there is often no solid intermediate organs, as in the lips, the linea alba, &c. The muscle of one side acts then directly upon that which corresponds to it, in order to distend it. Now this action of the muscles upon each other is precisely the phenomenon of the antagonists; two muscles are such when one cannot contract without elongating the other and vice versa. Let us examine in this phenomenon the part of the contractility of texture; it is necessary to distinguish its influence from that of the vital forces, which has not been heretofore sufficiently done.

A muscle once placed in the middle position, can only be removed from it by the influence of the vital forces, by the animal or sensible organic contractility, because in this position the contractility of texture of its antagonist is equal to its own, and there is consequently required a force added to this to overcome that which is opposed to it. But if the muscle is found in one of the two extreme positions, for example in adduction, abduction, flexion, extension, &c. then there will be an inequality of action in the antagonists, as it respects the con-

tractility of texture; the one most stretched, will make in order to contract itself, an effort much greater than that which is already contracted. To maintain the equilibrium, it is necessary then that the vital forces continue to influence the contracted muscles. Thus every extreme position of the limbs and of any moveable part, cannot in an ordinary state be supported except by the influence of the vital forces. When these forces cease to be in action, immediately the contractility of texture of the elongated muscle, which had a tendency to exert itself, but was prevented, exerts itself, becomes efficacious, and draws back the moveable part to the middle position, a position in which the equilibrium is restored. Hence why in all the cases in which the cerebral influence has no power over the muscles, in which they are not irritated by stimulants, the limbs are uniformly found in a medium position between extension and flexion, abduction and adduction, &c. This is the case in sleep, in the fœtus, &c. I have shewn elsewhere how the osseous arrangement of each articulation is adapted to this phenomenon, how every kind of relation between the articular surfaces, except that of this medium position, exhibits a forced state in which some ligaments are necessarily more stretched than others, and in which the osseous surfaces are never in so general contact as in this position. In certain fevers which have so deleterious an influence upon the muscular life and texture, the horizontal prostration and extension of the extremities do not arise from an increase of the action of the extensors, but from the want of energy of the flexors, which have not power to overcome the weight of the limb; thus observe that every analogous attitude always coincides with the signs of general weakness; this is the attitude of putrid fevers, &c.

The section of a living muscle presents us with two phenomena which are evidently the product of the contractility of texture.

1st. The two ends retract in opposite directions; there exists between these divided ends a space proportional to the retraction. This retraction is not in proportion, as has been thought, to the degrees of the contractions of the muscle; if it was, it would be sufficient in a transverse wound, in order to bring the divided edges together, to place the limb in the greatest possible relaxation; now oftentimes, in these cases, these ends still remain at a distance; then the retraction is often superior to the greatest contraction of the muscle considered in its natural state.

2d. The antagonist of the divided muscle which has no effort to overcome, contracts and makes the moveable part incline from its side, if there are not other muscles, which acting in the direction of the first supply its functions. This last phenomenon takes place also to a certain extent in paralysis of the face. The mouth is then drawn from the sound side. I have observed however in this respect, that this deviation is never as evident as it would be by the division of the paralytic muscle, which has preserved its contractility of texture. This remaining contractility forms a partial equilibrium with that of the muscles of the sound side, during the absence of motions; thus the deviations do not become very evident until the patients wish to speak, until consequently the vital forces bring into action the sound muscles, which the others cannot oppose. The paralysis of the sternomastoideus exhibits for the whole head a phenomenon analogous to that which the preceding muscles produce for the mouth. Strabismus also oftentimes arises from this cause.

In general in all the phenomena, it is necessary to distinguish that which belongs to the vital forces, from that which arises from the contractility of texture. The muscles are antagonists as it respects these forces, as well as it respects this contractility; now as the contraction de-

pendant on the nervous influence or irritability, is much more conspicuous than that arising from the organic texture, the phenomena of the antagonists are much more striking in paralysis, when the sound muscles are brought into action in the first manner. It appears that in many cases of paralysis, the contractility of texture of the affected side is also a little altered ; but it is never so completely destroyed, that in the amputation of a paralyzed limb, there is no muscular retraction. I have made this experiment upon a dog ; the nerves having been cut ten days before, and the limb having remained immoveable since that period, the division of the muscles produced a manifest separation between their edges ; and even, in afterwards cutting for the sake of comparison the limb that remained sound, I did not find any difference.

It is especially when muscles have been first stretched, and this stretching has ceased, that the contractility of texture becomes evident. The puncture in ascites and an accouchement as it respects the abdominal muscles, the opening of deep abscesses as it respects those of the trunk, the extirpation of a tumour situated under any muscle, &c. show us this property in action in a very striking manner. There is however an observation to be made on this point, viz. that if the extension has been of long continuance, or if it has been frequently repeated, the subsequent contraction is much less, because the muscular texture has been weakened by the painful state in which it has been ; hence, 1st, the flaccidity of the abdomen after repeated pregnancy ; 2d, the laxity of the scrotum, after the puncture of an old hydrocele ; 3d, I have seen at Desault's a man who was operated upon in Germany for a fungus in the mouth, and who had, on that side on which the disease had been, remarkable wrinkles, owing to the greater extent of the fleshy part of that side, which could no longer contract like the other ; mastication, at this time could only be performed on the sound side ;

4th, when women have had many children, the diaphragm is weakened by repeated pressure, and hence in part the greater mobility of the ribs, which compensate in some measure in females for the deficiency of action of this muscle. I think that in many chronic affections of the chest and abdomen, in which there is a long continued distension of this muscle, physicians ought more than they do, to have regard to this cause of difficulty of respiration, when the principle of distension no longer exists, as after the evacuation of dropsies, &c.

The extent of the contractility of texture is in the muscles in proportion to the length of the fibres ; hence why in amputations, the superficial part retracts more than the deep-seated ; why in sleep the phenomena of contractility of texture are very apparent in the extremities, the muscles of which are very long ; why, in the antagonists, nature has in general opposed muscles of proportional length ; why consequently, a muscle with long fibres has rarely for a counterpoise one with short ones, and vice versa. The flexors and extensors of the arm, the fore-arm, the thigh and the leg are nearly of the same extent ; the rotators of the humerus within and without, the first inserted into the sub-spinal depression, the others into the sub-scapular, resemble each other also in this respect. The proportion between the antagonists is still more remarkable on the face, where the same muscles act most commonly in an opposite direction on each side of the median line.

The quickness of the contractions, arising from the contractility of texture, is not like that produced by the animal or sensible organic contractility, which is uniformly more or less marked, according as the nervous influence of the stimulant acts more or less strongly. Every motion originating from the contractility of texture is slow, uniform and regular ; it is only when the muscular texture is weakened that it diminishes ; it does not

increase except when this texture is more developed; hence it follows that the varieties of quickness can only be observed in different individuals, or in the same individual at different periods, and not, as in the exercise of the vital forces, from one instant to another. This is a great and remarkable difference between the two species of properties.

Death weakens the contractility of texture but does not annihilate it; a muscle being cut retracts a long time after life has left it. Putrefaction alone puts a limit to the existence of this property. It is the same with regard to extensibility. I would observe however that while the muscles retain the vital heat, they have more power of retraction, than when the chill of death has seized them.

Haller places on the same line and derives from the same principles, the phenomena resulting from the contractility of texture, which, with some slight differences, answers to his dead power, and those produced by the action of the concentrated acids, alkohol, fire, &c. on animal substances, which crisp, contract and acquire the horny hardness from the effect of these different agents. But there are many differences which essentially separate these phenomena from each other. 1st. The contractility of texture is very slight in the organs in which the faculty of having the horny hardness is very evident, for example, in all the organs of the fibrous, fibro-cartilaginous, serous systems, &c. &c. 2d. The contractility of texture is distributed in very various degrees, to the different parts; from the muscles and the skin, which possess the greatest degree of it, to the cartilages which seem destitute of it, there are many variations; on the contrary, the faculty of acquiring the horny hardness from the agents pointed out is almost uniformly distributed, or at least its differences are much less evident. 3d. One becomes nothing in dried organs, the other is evidently preserved for many years, as parchment is a proof. 4th.

The first clearly receives an increase of power from life, especially in the muscles; the second appears to be hardly modified by it. 5th. This always exhibits sudden effects, rapid contractions. To feel the contact of the fire, of the concentrated acids or alkohol, and to assume the horny hardness, are two phenomena which the second brings together in the animal parts; the contractility of texture, on the contrary, exerts itself but slowly, as we have said. 6th. This last can never give to the parts, the muscles especially, that remarkable density which they exhibit in their horny hardening. 7th. The absence of extension of the fibres is the only thing necessary for the contractility of texture which has an unceasing tendency to activity; it requires on the contrary in order to crisp the fibres, that they should be in contact with a foreign body. I could add to these many proofs, in order to establish an essential difference between the phenomena confounded by the illustrious physiologist of Switzerland.

II. *Vital Properties.*

The most of these properties perform a very important part in the muscles. We shall first examine those of animal life, and afterwards treat of those of organic.

Properties of Animal Life. Sensibility.

Animal sensibility is that of all the vital properties which is the most obscure in these organs, at least if we consider them in the ordinary state. Cut transversely in amputations, in experiments upon living animals, they do not experience any very painful sensation; it is only when a nervous filament is touched, that pain is manifested. The peculiar texture of the muscle is but slightly sensible; irritation by chemical stimulants does not show much sensibility in it.

There is however a peculiar sensation, which in the muscles very evidently belongs to this property; it is that which is experienced after repeated contractions, and is called lassitude. After long standing, it is in the thick bundle of lumbar muscles that this sensation is especially felt. After walking, running, &c. if on a horizontal plain, it is all the muscles of the lower extremities which are more particularly fatigued; if on an ascending plain, it is especially the flexors of the ilio-femoral articulation; if on a descending one, it is the posterior muscles of the trunk. In the employments which exercise particularly the superior extremities, this sensation is often experienced in a remarkable manner, which is certainly not owing to the compression made by the muscles in contraction, upon the small nerves which run through them. In fact it can take place without this antecedent contraction, as is observed in the commencement of many diseases, in which it extends in general over the whole muscular system, and in which the patients are, as they say, fatigued and wearied, as after a long march. This sensation appears to depend on the peculiar kind of animal sensibility of the muscles, a sensibility which the other agents do not develop, and which the permanency of contraction renders here very apparent. Thus the fibrous system, sensible only to the means of distension which act upon it, does not receive a painful influence from the other agents of irritation. Observe that this painful sensation, which a too prolonged motion produces in the muscles, is intended by nature to warn the animal to place limits to it, without which the consequences would be serious. Thus the peculiar sensation which arises from distended ligaments, is designed to make the animal limit their extension. Observe how each organ has its peculiar kind of sensibility; how false an idea we should have of the existence of this property, if we judged of it only from mechanical and chemical agents, and observe

particularly how nature accommodates to the uses of each organ its kind of animal sensibility.

In phlegmasia of the peculiar muscular texture, the animal sensibility is very often raised to a very great height; the least touch on the skin becomes painful; the patient can hardly bear the weight of the clothes, and frequently the least jar produces in the limbs the most acute pains. But in general these pains are wholly different from the painful sensation which we call lassitude; thus the pain of a ligament stretched in a sound state, is not the same as that which arises from the inflammation of a ligament or any other fibrous organ.

I would add to what I have said above upon this sensation, that some organs are fatigued like the muscles, from too long continuance of their functions; for example, the eyes by the contact of light, the ears by that of sounds, the brain by thinking, &c. and in general all the organs of animal life; it is even this general lassitude which brings on sleep, as I have proved in my Researches upon Life. But observe that the sensation which the eye, the ear, the brain and all the external organs produce when thus fatigued is not the same as that which arises from the over-exertion of the muscles; another proof of the peculiar kind of their sensibility, and in general of that of every living part.

Animal Contractility.

This animal property, upon which all the phenomena of locomotion and voice depend, which assists those of the internal and external functions, has its seat exclusively in the animal muscular system; it is this which distinguishes it from the organic, and from all the others. It consists in the faculty of moving under the cerebral influence, whether the will or other causes produce this influence. The animal contractility has then, like the sensibility of the same species, a peculiar character, differing

from the two organic contractilities, a character which consists in this, that its exercise is not concentrated in the organ which is moved, but that it requires also the action of the brain and the nerves. The brain is the principle from which, if we may so say, this property goes, as it is that to which all the sensations come; the cerebral nerves are the agents which transmit it, as they are, though in an opposite direction, the conductors of the sensitive phenomena. Whence it follows, that in order to understand this property well, it is necessary to examine it in the brain, in the nerves and in the muscle itself.

Animal Contractility considered in the Brain.

Every thing in the phenomena of animal contractility proclaims the influence of the brain.

In the ordinary state if more blood is carried to this organ, as in anger; if opium, taken in a moderate dose, excites it slightly; if wine produces the same effect, the muscular action increases in energy in proportion as that of the brain is thus increased. If terror by retarding the pulse, by diminishing the force of the heart, and even the quantity of blood sent to the brain, strikes it with atony; if the different narcotics, carried to excess, produce the same effect; if wine prevents its action by its too great quantity, then observe these muscles languish in their motion and experience even a remarkable intermission. If the brain is wholly engrossed in its relations with the senses, or in its intellectual functions, it, if we may so say, forgets the muscles; these remain inactive; the man who looks or hears with attention, does not move; neither does he who contemplates, meditates and reflects. The phenomena of ecstasy, the history of the studies of philosophers, often present us with this important fact, this muscular inertia, the principle of which is in the distraction of the cerebral influence, which does not increase in other functions, only by diminishing in locomotion.

In diseases, all the causes which act strongly on the brain, re-act suddenly on the animal muscular system; now this reaction is manifested by two opposite states, by paralysis and by convulsions. The first is the indication of diminished energy, the second that of increased; one takes place in compressions from pus, effused blood, bones driven below their natural level, and from the consequences of apoplexy; it is seen in the attack of most hemiplegias, a sudden attack in which the patient falls down, loses all consciousness and has all the signs of a cerebral lesion. This lesion disappears, but its effect remains, and this effect is the immobility of a part of the muscular system. The other state or the convulsive, arises from the various irritations of the cerebral organ from osseous fragments driven into its substance, from its own inflammation or that of its membranes, from different tumours of which it may be the seat, from organic lesions that it may have, lesions which I have rarely observed in the adult, but which infancy sometimes exhibits, and from the causes even of compressions; for oftentimes we see this convulsive state existing at the same time with different effusions, with hydrocephalus, &c.

The state of the animal muscular system is truly the thermometer of the state of the brain; the degree of its movements indicates the degree of energy of this organ. Those who attend in a lunatic hospital have often occasion to consult this thermometer. At the side of a furious patient, whose muscular power is doubled, or even trebled, you see a man all whose motions languish in a remarkable inertia. A thousand different degrees are observed in these motions; now these degrees do not depend upon the muscles; the most furious madman is often he whose very delicate external forms indicate the weakest muscular constitution; as the most perfect automaton is sometimes he whose muscles are the most powerfully developed. The muscles are to the brain

what the arteries are to the heart. The physician learns by these vessels the state of the central organ of circulation which communicates impulse to them; by the muscles of animal life, he learns the state of the central organ of this life. Observe patients in many important fevers; in the morning there is prostration, in the evening you find an extreme agitation in the muscles. Now what is the seat of this revolution? It is not the muscles, but it is the brain. There has been a translation to the head, as it is commonly called.

If from the bed of the sick we go to the laboratory of the physiologist, we shall see experiments in perfect accordance with the preceding observations. The ligature of all the arteries that go to the brain, interrupts immediately the movements of this organ, movements necessary to its action, and produces a sudden cessation of voluntary motion, and afterwards death. By injecting through the carotid and towards the head, ink, solutions of neutral salts, acids, substances whose contact is fatal to cerebral action, I have always seen the animal perish with previous convulsive motions. The injection of water does not produce this effect; it can with impunity to the life of the brain be introduced into the arterial blood, if it is injected moderately; but pushed with force, you will irritate extremely this organ, and in an instant the animal is seized with violent agitations; moderate the force, rest succeeds. I have already related this experiment elsewhere. If we lay bare the cephalic mass, and irritate it with a mechanical or chemical agent, &c. in an instant the animal muscular system is brought into action. It is however to be observed that in these experiments the convexity of the organ appears to be much less connected with the motions, than its base. The irritation confined to the cortical substance, to the superficial layers of the medullary, is almost nothing; it is not till we arrive at the inferior layers, that the convulsions come

on. I have wished to try many times to ascertain with precision the place where the irritation becomes a cause of convulsion; but this has always appeared to me very difficult, and the results have been infinitely various. I believe that we can hardly establish any thing more than a general result, viz. that the nearer we approach in the experiments the annular protuberance, and in general the cerebral base, the more apparent are the convulsive phenomena; they are so much the less as we remove from them, they are nothing on the convex surface. Observe that it is on the side of its base, that is to say, on the side of its essential part, that the brain receives the numerous vessels which carry to it excitement and life, whether by the motion which they communicate to it, or by the nature of the red blood which they carry to it, as my experiments published the year passed have, I think, demonstrated.

Add to these experiments those of the artificial commotions. The muscles of the ox vacillate, and are unable to support themselves, the instant the blow is struck. At other times animals expire, their limbs convulsively agitated from a blow given on the occiput; rabbits often exhibit this phenomenon. Pigeons die with convulsive motions of the wings. Irregular agitations arising from an irregular influx of the power of the brain always precede the instant of death, which the commotion has produced.

Let us conclude from all these experiments and the observations that precede them, that the action of the animal muscular system is always essentially connected with the state of the brain, and that when this action is increased or diminished there is almost always an increase or diminution of the cerebral action.

Let us not however exaggerate the relation which connects the muscular to the cerebral phenomena; observation would prove us incorrect. There are various exam-

ples of aqueous, sanguineous and even purulent congestions in the brain, without having produced any alteration in muscular motion. Different tumours and defects of conformation have occasioned disturbance of the intellectual functions, without affecting those of the muscles; how many times is the brain disordered in various species of alienations; how many times do the understanding, memory, attention and imagination indicate these derangements by their irregular aberrations, without their being felt by the muscular system. Is there not often an alteration of the external sensation, without an alteration of motion? In general the brain has three great functions. 1st. It receives the impressions from the external senses; it is in this relation the seat of perception. 2d. It is the principle and the centre of the voluntary motions, which are not exerted but by its influence. 3d. The intellectual phenomena are essentially connected with the regularity of its life; it is as it were the seat of them. Now it can be deranged as to one of these functions, and remain sound as to the others; it can be a regular principle of the motions, and an irregular centre of the phenomena of the understanding; not communicating with external objects by the senses, and determining motions, or presiding over intellectual functions, as happens in sleep which is disturbed by dreams, &c.

From what has been said we can understand why acephalous fœtuses cannot live out of the womb of the mother. As animal life is nothing in the fœtus, as respiration does not take place, as the functions are limited to the great circulation, to the secretions, exhalations and nutrition, the acephalous fœtuses can live in the womb of the mother, and acquire a very considerable size; but at birth they cannot breathe, the intercostals and diaphragm being unable to act. The gastric viscera receives no influence from their muscular parietes; all the limbs are immoveable. Animal life, which commences in

others at birth, cannot commence in them, because they have not the centre of this life; they have senses, but nothing to receive their impressions; muscles, but nothing to make them move; they can continue to live but a little while in themselves, without beginning to live from without. But as in general it appears that when the infant quits the wômb, the red blood becomes necessary to it, that to have this, it must respire, and as this function cannot commence, it loses the internal life which it had in the womb of the mother. There are acephalous fœtuses which have at the origin of the nerves a small medullary swelling; in others the spinal marrow is larger. If these medullary swellings, if the spinal marrow by its peculiar texture, supply the place of the brain, life can continue, and it is in this way that we can explain some examples of acephalous subjects that have lived a certain time. But certainly an acephalous subject organized like ourselves, which has nothing to supply the place of the brain, cannot live. Thus in almost all the examples of these monsters, related by authors, and especially by Haller, the death of the individual took place at its birth.

Animal Contractility considered in the Nerves.

The brain, at a distance from almost all the muscles, communicates with them by the nervous system, and by it transmits to them its influence; now this communication is made in two ways. 1st. There are nerves which go directly from the brain to the muscles of animal life. 2d. The greatest number does not go from this organ itself, but from the spinal marrow. Almost all the muscles of the neck, all those of the chest, the abdomen and the extremities receive theirs from this last source. The spinal marrow is, as it were, a general nerve, of which the others are only divisions and principal branches.

All the lesions of this principal nerve are felt by the muscles that it has under its influence; the compressions

that it experiences from a fracture of the vertebræ, from any displacement, from an effusion of blood, serum, pus, &c. in the vertebral canal, the derangements which take place from a violent blow received upon the whole region of the spine, from a fall upon the loins, or on the superior part of the sacrum, are followed by numbness and paralysis of the subjacent muscles. Divide the spinal marrow, by introducing a scalpel into the canal, immediately all motion ceases below the division. If you wish on the contrary to produce convulsions, introduce a stilet into the canal; irritate the marrow with it or by chemical agents placed on it, there will be immediately agitation and convulsion in all the animal and muscular system that is below.

The higher the lesion of the marrow is, the more dangerous is it. In the lumbar region its influence extends only to the inferior extremities, and the muscles of the pelvis; in the back it paralyzes these muscles and those of the abdomen; now as these last contribute indirectly to respiration, this function begins to be embarrassed; if the lesion is above the dorsal region, it becomes still more painful, because the intercostals lose their action; the diaphragm alone then supports the respiratory phenomena, because the phrenic nerve still receives and transmits the cerebral influence. But when the lesion happens above the origin of this nerve, there is no more action of the diaphragm, and no more contraction of the intercostal and abdominal muscles; respiration ceases; from the same cause the circulation is interrupted; the blood being no longer carried to the brain, the action of this organ is annihilated. Hence why the luxations of the first vertebra on the second are suddenly fatal, when the displacement is very great; why judicious surgeons dare not sometimes run the hazard of reduction, when these luxations are partial, for fear of rendering them complete, and of thus seeing the patient, whom they attempted to relieve, perish

in their hands; why, when we wish to knock down an animal, the blow should be given on the superior and posterior part of the spine; and why a stilet plunged between the first and second vertebræ immediately destroys life.

We see very distinctly the successive influence of the different parts of the marrow on the muscles and on the general life, by introducing a long piece of iron into the inferior part of the vertebral canal of an animal, of a guinea pig for example, and carrying it up through this canal to the cranium, through the spinal marrow which it tears. We observe evidently as it ascends, at first convulsions of the inferior extremities, then those of the abdominal muscles, then derangement of respiration, then its cessation, then death which is the consequence of it.

From all these facts, we cannot, I think, call in question the influence of the spinal marrow upon motion, the principle of which it receives from the brain and afterwards transmits it to the nerves. These last carry this principle, which they have received, to the muscles, either by means of the spinal marrow, as in almost all those of the trunk and the extremities, or directly from the brain, as in those of the face, the tongue, the eyes, &c. There are the same proofs for this nervous influence, as for that of the preceding sensitive organs. The tying, division or compression of a nerve paralyzes the corresponding muscle. Irritate with any agent a nerve laid bare in an animal, convulsive contractions are immediately seen in the muscle. These experiments have been so often and so accurately repeated by many authors, that I think it useless to go into details, which the reader may find everywhere. Irritation continued some time upon one point of the nerve destroys its influence upon the muscle, which remains immoveable; but it is put in motion again, if the irritation is carried to a lower part of the nerve.

If we tie it, the motion ceases, if irritation is made above the ligature, it returns when it is made below, or when the ligature is removed.

I would remark that all the nerves of animal life do not appear to be equally capable of transmitting to the muscles the different irradiations of the brain. In fact whilst in diseases, in wounds of the head, in our experiments, &c. the muscles of the extremities are convulsed or paralyzed with great ease, those of the abdomen, the neck, and especially the chest do not exhibit these phenomena, except when the causes of excitement and debility are carried to the highest point. Nothing is more frequent than to see the abdomen and the chest with their ordinary degree of muscular contraction, whilst the extremities or the face are agitated with convulsive motions. Examine most hemiplegias ; the mouth is twisted, the superior and inferior extremity of one side become immoveable, and yet the pectoral and abdominal motions continue. Those of the larynx are more easily interrupted than these in paralysis ; hence the different injuries of the voice. We could make a scale of the susceptibility of the muscles to receive the cerebral influence, or of the nerves to propagate it, for it is difficult to determine to which of these two causes the phenomenon is owing ; we could, I say, make a scale, at the top of which should be placed the muscles of the extremities, then those of the face, then those of the larynx, afterwards those of the pelvis and the abdomen, and finally the intercostals and diaphragm. These last become convulsed and paralyzed with the most difficulty of all. Observe how this scale is adapted to that of the functions. What would become of life, which is always actually connected with the soundness of respiration, if all the cerebral lesions were as easily felt by the diaphragm and the intercostals, as by the muscles of the extremities? Paralysis in these last only takes from the animal a means of communication with external objects ;

in the others it interrupts immediately both internal and external life.

The nervous influence is only propagated from the superior to the inferior part, and never in an inverse direction. Cut a nerve in two, its inferior part when irritated will make the subjacent muscles contract ; let them do what they will to excite the other, no contraction is produced in the superior muscles ; so the spinal marrow divided transversely and pricked above and below, produces no sensible effect but in the second direction. The nervous influence never extends upward for motion, as it does for sensation.

Animal Contractility considered in the Muscles.

The muscles essentially destined to receive the cerebral influence by means of the nerves, have however an active part in their own contraction. It is necessary that they should be entire to exercise this property, and answer to the excitement of the brain. When any lesion affects their texture, and it is no longer the same as usual, the muscle remains immoveable or moves with irregularity, though it receives a regular nervous influx. The following are various circumstances relative to the muscle itself, which prevent or alter its contractions.

1st. An inflamed muscle does not contract ; the blood which then infiltrates it and penetrates its fibres, their great excitement and the increase of its organic forces, do not permit it to obey the stimulus it receives. In angina, deglutition is as much interrupted by the inaction of the muscles, as by the inflammation of the mucous membrane. We know that the inflammation of the bladder is one cause of the retention of urine ; that of the diaphragm renders respiration very painful, which the intercostals perform almost alone.

2d. Every thing which tends to weaken and relax the muscular texture, as external blows, bruises, contusions,

infiltrations of serum in dropsical limbs, or distension from a subjacent tumour long continued, alters, changes the nature of, and can even annihilate animal contractility.

3d. Whenever the blood ceases to enter the muscles by the arteries, these organs remain immoveable. Steno has observed, and I have always seen, that in tying the aorta above its bifurcation which forms the internal iliacs, paralysis of the inferior extremities immediately comes on. We know that in the operation for aneurism, a numbness more or less considerable almost always follows the ligature of the artery. This numbness continues until the anastomoses supply the place of the artery which no longer brings any fluid. The internal motion created in the muscle by the entrance of the blood, is then a condition essential to muscular contraction. Thus the habitual motion imparted to all the other organs and especially to the brain, maintains their excitement and their life.

4th. It is necessary in order to obey the cerebral influence that the muscle should not only receive the shock of the blood, but also of the red or arterial blood. Black blood cannot by its contact support motion. A general weakness and the fall of the animal are the first symptoms of asphyxia, a disease in which the black blood goes to all the parts. I shall not here repeat the proofs of this assertion, which appears to me to be amply demonstrated by my Researches upon the Different Species of Death. I refer to my work upon this point.

5th. A fluid differing from the blood, water, oily and albuminous fluids, and for a stronger reason acrid and irritating fluids, the urine, solutions of the acids and the alkalis, &c. are not proper to support muscular action; on the contrary they paralyze it; injected into the crural arteries of a living animal instead of blood, which is stopt above by a ligature, they weaken and even annihilate the motions, as I have frequently satisfied myself. The result varies in these experiments according to the fluid em-

ployed in making them; the rapidity of the cessation of the motions is more or less striking; they are either weakened or totally suspended; but there is always a very great difference between that and the natural state.

6th. Does the contact of the different gases upon the muscles modify their contractions? Since the publication of my Treatise upon the Membranes, I have made no experiment upon this point. Those which are contained in it present the following results; frogs and guinea pigs rendered emphysematous by blowing air into the sub-cutaneous texture which afterwards penetrates the cellular interstices, and comes everywhere in contact with the muscular system, move almost the same as usual. If oxygen is used, the motions of the emphysematous animals are not accelerated; they are not diminished if we employ the carbonic acid gas, hydrogen, &c. In general, all the artificial emphysemas that I have made upon the two species mentioned, in order to have an example in each class of animals with red and cold blood, and of those with red and warm blood, succeeded very well, and did not appear to cause any sensible embarrassment to the animal, which gradually got rid of it. Emphysema with nitrous gas is constantly fatal; the contact of this gas seems almost suddenly to strike the muscles with atony.

7th. If instead of blowing gas into the cellular texture of an animal, we force in different fluid substances, they produce different effects upon the muscles, according to their nature, and to their acrid, soft, or styptic qualities. No injection produces a more sudden and striking effect than that of opium dissolved in water, or than that of its various preparations; when the muscles feel it in contact, their motions cease, they fall as in paralysis.

In general I would observe that it is infinitely better to make the experiments of the contact of the gases and the different fluids upon the muscles, by blowing the first, and injecting the others into the intermuscular texture of

a living animal, than by drawing out a muscle, and afterwards plunging it all alive into the one or the other; or than laying a muscle bare, in order to direct upon it the current of a gas, or to moisten it with a fluid, for the purpose of observing the phenomena of the contact.

It follows from all that we have just said, 1st, that to answer to the cerebral excitement by contracting, the muscle should be in general in a state determined by the laws of its organization; that out of this state it is not capable of contracting, or at least that it does it feebly and irregularly; 2d, that the contact of different foreign substances produces upon the muscle a very variable effect. Moreover many causes besides those stated above, appear to me also to alter the contractions, by acting directly upon the muscles, such as mercury taken by friction for the venereal disease, the influence of this metal, of copper and of lead, upon those who work in them, the action of cold, that of certain fevers, &c. The muscular tremor arising from these different causes, does not appear to arise from the brain; this organ at least does not most commonly give any sign of affection in this case; I confess however that in these different species of tremors, it is not easy to distinguish that which belongs to the peculiar affection of the muscle, from what arises from that of the nerves; perhaps these are especially affected, but the brain certainly does not participate.

Causes which bring into action Animal Contractility.

We have just seen that in the natural state this property constantly requires three actions, 1st, that of the brain; 2d, that of the nerves; 3d, that of the muscles; that it is from the brain that the principle of motion goes which is propagated by the nerves, and which the muscles receive. But it is necessary that some agent should excite the brain to determine it to exert its influence. In fact, the animal contractility being essentially intermittent in its

exercise, so that each time after it has been exerted it is suspended, it is necessary that a new cause should place it again in activity; now this cause acts at first upon the brain in the natural state.

I refer to two classes the causes that excite the brain in order to produce animal contractility. In the first is the will, in the second are all the impressions which this organ receives, and which are not under the control of the mind.

The brain is only intermediate between the mind and the nerves, as the nerves are between the muscles and the brain; the principle, which wills, acts at first upon this organ, which afterwards re-acts. When they are thus produced, our motions are sometimes precise and regular; that is when the intellectual functions are sound, when the memory, imagination and perception are clearly exerted, when the judgment being correct, directs with regularity the acts of the will; sometimes they are irregular and singular, it is when the intellectual functions disturbed and agitated in various ways, produce a singular and irregular volition, as in the various mental alienations, in dreams, in the delirium of fevers, &c. But in all these cases, these are always voluntary motions; they go from the immaterial principle that animates us.

In the second class of causes which influence the brain, the animal contractility becomes involuntary; it is exerted without the participation of the intellectual principle, often even against its will. Observe an animal whose brain is artificially irritated in experiments; it tries to stiffen itself to prevent the contractions, they take place in spite of it; prick a nerve in an operation, the muscle contracts suddenly below, without the mind's participating in this movement; the patient has not even a consciousness of it; he has only that of the pain. When much blood flows to the brain in the violence of inflammatory fevers, this organ excited by the fluid, re-acts immediately

upon the muscles, without the will's partaking in it. All the phenomena of contraction and relaxation, arising from different accidents which accompany wounds of the head, cerebral inflammations, &c. are equally involuntary, although having their seat in the muscles which the will habitually directs. These are the different circumstances in which the action of any agent upon the brain is direct and immediate, and in which there is a mechanical cause applied to the brain.

In other circumstances the brain is only affected sympathetically. In many acute affections what is called translation to the brain, does not arise from more blood being carried to it; the pulse is not fuller, the face is not more flushed; there are often even signs of languor in the action of the vascular system. The brain is affected, like all the other organs by sympathy, a happy word, which serves to veil our ignorance in respect to the relations of organs to each other; the brain is affected then like the heart, the liver, &c. Take for example peripneumony; the lungs are then the organs that are essentially injured, from this essential and local injury, arise many sympathetic ones more or less severe. If the liver is sympathetically affected, bilious symptoms are joined to the symptoms of the principal affection; if it is the stomach then gastric symptoms are manifested. The heart is always agitated; hence there is fever. When the sympathetic influence extends to the brain, there is violent motion, convulsions, &c.; for, as I have said, the state of the muscles is the index of the state of this organ; now, in this last circumstance, the will has nothing to do with the animal contractility in exercise; the patient cannot prevent the convulsive agitation of his muscles; the sympathetic irritation of the brain is stronger than the influence of the will. This example of cerebral affection in peripneumony, though more rare than in many other diseases, may however give us an idea of what takes

place in all other cases in which the muscles are convulsively agitated by the injury of any organ, by that of the fibrous system distended, of the ligaments and especially of the aponeuroses, by dentition, by violent pains in the kidneys, in thes alivary glands or the pancreas, occasioned by a stone, by injuries of the diaphragm, the nerves, &c. In all these cases, there is an affected point in the economy; from this point the sympathetic irradiations go off, which especially reach the brain; this irritated by them, enters into action and excites the muscles; their contraction takes place and the will is a stranger to it.

See also how the passions which have their influence particularly over the internal organs, which especially affect those placed around the epigastric centre, the heart, the liver, the stomach, the spleen, &c. imprint on our motions an impetuosity, which the will cannot make us masters of. The internal organ affected re-acts upon the brain, this excited stimulates the muscles; they contract, and the will is almost nothing in this contraction. Observe the man, whom jealousy, hatred or rage agitates to the greatest degree; all his movements follow each other with an impetuosity which judgment reproves, but which the will cannot moderate, so much does the influence of the sympathetic affection of the brain predominate over that of the will. At other times the passions exhibit an opposite phenomenon. They are marked by a general weakness of all the muscular motions. In astonishment accompanied with grief, or in that in which is mixed a lively joy, the arms fall down as it is commonly expressed; the cerebral influx ceases almost entirely, and yet it is not to the brain that the influence of this passion is carried, it is to the epigastric centre, as is proved by the sudden contraction which is felt there. One of the epigastric organs has been affected; it has reacted upon the brain; this has been interrupted in part in its functions; the muscles feel it and theirs cease. In fear in which

this phenomenon is observed, as the paleness of the skin indicates the languor of the circulating system, it may happen that the cerebral and muscular inaction arises in great measure from this, that there is not received a sufficient impulse from the heart, upon which the first influence of the passion is exerted, and which by this influence is retarded in its motions. Fear, it is said, takes away the legs, petrifies, &c.; these expressions, borrowed from vulgar language, indicate the effect of this passion on the muscles; but this effect is only secondary; the first influence has been upon the heart, the second upon the brain; it is not till after the other two that the muscles are affected. Hence how certain animals remain immoveable at the sight of that which is about to seize them for its prey.

It is also to the sympathetic influence of the internal organs upon the brain, that should be attributed the motions of the fœtus, motions which the will does not direct; for the will is but a result of the intellectual phenomena; now these phenomena are nothing at this period of life. The internal functions then very active, suppose a great action in the liver, the heart, the spleen, &c.; now these organs in that way influence efficaciously the brain, and this in its turn puts the muscles in motion; so that the animal contractility is by no means voluntary in the fœtus; it does not begin to become so until the sensations have brought into action the phenomena of the understanding; until then, they must be compared to all those of which we have spoken above.

From all that has just been said, it will be easily understood, I hope, how the animal contractility can be or not subjected to the influence of the will. In both cases, the series of phenomena which it requires is always the same; there is always excitement by the brain, transmission by the nerves, execution by the muscles, or successive inactivity of these three organs. The difference is only in

the cause which produces the cerebral excitement; now this cause can be, 1st, the will; 2d, an irritation immediately applied; 3d, a sympathetic irritation. It is essential to form precise and exact ideas concerning this vital force which performs so great a part in the living economy.

Duration of the Animal Contractility after Death.

The difference of the causes which act upon the brain in the animal contractility, in order to determine it to excite the muscles, appears particularly in a remarkable manner at the instant of death. Whatever may be the way in which this happens, the intellectual functions are always the first to cease; it is even to this that we especially attach the idea of the absence of life. Whence it follows that the first phenomenon of this absence must be the failure of the muscular contraction subjected to the influence of the will, which is the result of these intellectual functions. Every thing then remains immoveable in the muscular system, if no other cause acts upon the brain or the nerves; but these two organs are, yet for a long time, capable of answering to the various excitements of stimuli. Stimulate in any way the brain, the spinal marrow or the nerves of an animal recently killed, in an instant its muscles convulsively contract; it is the same phenomenon as that obtained during life from the same cause. Often even immediately after death, this phenomenon is still more apparent than during life; I have been frequently convinced of this in my experiments. If during life we irritate any nerve, the contraction oftentimes is almost nothing, because the will acting by the other nerves upon the same muscle, or at least upon those of the limb, produces contractions opposite to those which the irritation tends to produce. I have many times observed that the galvanic phenomena are also infinitely more easily produced an instant after death, even

in animals with red and warm blood, than during life: in this last case often we can obtain hardly any result, because their influence is counteracted by the cerebral influence arising from the will. When the irritation is directly applied to the brain or the superior part of the spine, it then surpasses the will; it is stronger in the living animal; but on an insulated nerve, it is often inferior to it; not that the will acts by the irritated nerve, its influence in it is arrested at the place stimulated, but it exerts itself by the adjacent nerves.

It is to the susceptibility of the brain and nerves of still transmitting the principle of motion after death, that must be referred all the phenomena that are witnessed in the different kinds of decapitation. Ducks, geese and other animals of this family move their muscles with some regularity, after the head is taken off, in running, jumping, &c. Some time after the punishment of the guillotine, the inferior and superior extremities are still the seat of various tremors; the muscles of the face are sometimes even contracted so as to give to this part the expression of certain passions, an expression incorrectly referred to the sensitive principle still left for some time in the brain. The same phenomena were formerly observed in the punishment that consisted in cutting off the head with an axe. During the year past I have had a painful proof of these singular facts; a guinea-pig, whose heart I had just removed, plunged deep into my finger the four prominent teeth that distinguish this species. All these phenomena are only the result of the irritation produced, either by the cutting instrument, or by the air, upon the two divided extremities of the marrow; this is so true, that by increasing the irritation by a pricking, cutting instrument, &c. with a chemical agent applied to these extremities, the motions are very much increased. Nothing is more easy than to be convinced of this fact in an animal; I have many times proved it in those who

have been guillotined, upon whom I have been allowed to make experiments for galvanic purposes. See how the alternate motions of respiration can continue for some time, after the brain has been destroyed, after a wound of the head in which its mass has been crushed, after a luxation of the first vertebra, in which the beginning of the spinal marrow has been compressed so as suddenly to stop life, after the injection of a very irritating fluid by the carotid, &c. &c.

In this duration of animal contractility after death, the muscles are absolutely passive; they obey, as during life, the impulse they receive from the nerves; it is this which distinguishes it essentially from the duration of irritability, a property by which, after death as during life, the muscle has in it the principle which makes it move.

The duration is greater or less according to the class of the animals; those with red and cold blood keep this property longer than those with red and warm blood; among these, the family of ducks are, as I have said, remarkable for this phenomenon, which is much more rapidly lost in the others and in quadrupeds. In the first class there are also varieties among the reptiles, fishes, &c.

In general I have constantly observed that the animal contractility ceases after death, first in the brain, then in the spinal marrow and last in the nerves. When the muscles no longer move by irritating the first of these organs, they contract by stimulating the others. The irritated nerves can still communicate a motion, when the spinal marrow, no longer exhibits this phenomenon. I have not observed that the superior part of the nerve ceased sooner to transmit motion, than the inferior. But what is remarkable is that certain nerves, under the influence of the same irritation, make their muscles contract more strongly than others; such for example is the

phrenic. When all the other muscles cease to be moveable by the artificial excitement of their nerves, the diaphragm is still moved by this means. Whilst experiments have but little effect elsewhere, they are in full force upon this muscle; this is the more remarkable, as during life this is precisely the one which is the least affected by the state of the brain and the spinal marrow; paralysis and convulsions hardly ever affect it, as we have seen.

Besides, in thus comparing the duration of animal contractility, the same stimulant should always be employed; for the effects are more or less evident according to those which we use. When the whole brain and the nerves are no longer sensible to mechanical or chemical agents, they still powerfully obey galvanic impulses. The irritation of the metals is of all the means at present known, the most efficacious in perpetuating animal contractility some time after death.

Organic Properties.

Organic sensibility is the manifest portion of the muscles of which we are treating; constantly brought into action in them by nutrition, absorption and exhalation, it becomes still more apparent, when we irritate muscles that are laid bare; they feel this irritation, and the motion, of which we shall speak hereafter, is the result of this feeling which is centred in the muscle, and which is not referable to the brain.

Insensible organic contractility is the attribute of this muscular system, as of all the others.

The sensible organic contractility is very evident in it. If we lay bare a muscle in a living animal, and irritate it with any agent, it curls up, contracts and is agitated. A detached muscular portion exhibits for some instants the same phenomenon.

Every thing is irritating to the naked muscle, the air, water, neutral salts, the acids, the alkalis, the earths,

metals, animal and vegetable substances, &c. The mere contact is sufficient to produce contraction. Yet besides this contact, there is something also which depends upon the nature of the stimuli, and which makes the intensity of the contractions vary. A powder of wood, coal, metal, &c. sprinkled upon the muscles of a frog, produce but slight motions in it; pour on it a neutral salt in powder, the marine salt for example, immediately irregular agitations, and a thousand different oscillations are manifested. Each body is by its nature capable of irritating the muscles differently, as according to individuals, ages, temperaments, seasons, climates, &c. the muscles are capable of answering differently to excitements made upon them.

It is not necessary to irritate the whole of a muscle to produce its contraction; two or three fibres only being pricked bring into action all the others. Often even when we make these experiments on a living animal, the contraction is communicated from one muscle to another. In general I have constantly observed that during life these experiments are less easy, and give results much more various, as we have already stated with regard to animal contractility. Lay bare a muscle, irritate it at many different times; sometimes it does not give the least sign of contractility; sometimes it moves with force; this varies from one instant to another. Whereas if it is upon an animal recently killed that the experiments are made, the results are always nearly the same in a given time, with the difference however of the weakness which the contractions have in proportion to the length of time after death. It never happens that you see a muscle immoveable under stimuli, which is not rare in a living animal. This essential difference which authors have not sufficiently pointed out, and which I have frequently proved upon different animals, arises from this, that during life, the effects of the nervous influence coun-

teract those of the stimuli; for example, if an animal extends with force his thigh by the posterior muscles, we may in vain irritate the anterior ones, we cannot produce flexion by this irritation. The cerebral excitement in the extensors being stronger than the mechanical excitement in the flexors, triumphs. Often when we apply the stimulant, the brain acts with force upon the muscle, the effect is then much superior to the excitement we have applied. We are astonished; but the astonishment ceases, if we recollect that there is a concurrence of two excitements, of that of the external agent and of that of the brain. In general, those who have made experiments, have not paid sufficient attention to this concurrence of the two forces in a living animal.

In order to estimate correctly the sensible organic contractility, it is necessary to destroy the animal contractility. So long as these two clash, interrupt and counterbalance each other, we cannot properly estimate them, and determine what belongs to each and what is common to both. Now we destroy animal contractility in the living subject, by cutting all the nerves of a muscle or an extremity, which then become paralyzed. The brain can no longer act upon them, and the results we obtain from stimuli, belong to the sensible organic contractility.

The duration of this last property, after the experiment I mentioned, proves completely that the nerves are wholly foreign to it, that it resides essentially in the muscular texture, that it is, as Haller said, inherent in it. Thus whilst in the different paralyses the muscles lose the power of obeying the cerebral influence, or rather this influence becomes nothing, they preserve that of contracting in an evident manner when stimulated.

This contraction of the muscles of animal life by stimulants, appears under two very different modes. 1st. The whole of the muscle can contract and shorten so as to approximate the two points of insertion. This happens in

general when death is recent, when the muscle is still fully possessed of life. 2d. There are oftentimes numerous oscillations of the fibres; all are in action at the same time; now this action is not a contraction, but a real vibration, a fluttering, which has not a sensible effect upon the whole of the muscle, which not contracting cannot approximate its moveable points. When life is about abandoning entirely the muscle, it is thus that it moves. The diversity of the stimuli occasions also this double mode of contraction. Carry a scalpel over a living muscle, a contraction of the whole will be the consequence; afterwards sprinkle the same muscle with a neutral salt, sometimes there is an analogous contraction; but frequently there are only oscillations, vibrations similar to those of a muscle which life abandons.

During the life of the animal, its sensible organic contractility is rarely in action, because the muscles have not agents that act upon them in a sensible manner at least. Why then is this property so developed in them? I cannot determine.

All the muscles do not possess it to the same degree; the diaphragm and the intercostals are the most irritable; they are also those whose organic contractility is the most permanent after death. Observe that this contrasts, like their susceptibility to receive the nervous influence by the irritation of their nerves, especially of the phrenic, with the little disposition they have to feel, during life, convulsions or paralysis. After them I think that the temporal, the masseter, the buccinator, &c. are the most irritable. There is certainly as it respects irritability a great difference between them and the muscles of the extremities, which are all nearly equally susceptible to the effect of stimulants. Besides, it is only by a great number of experiments that we can establish general data; for nothing is more frequent than to find inequalities be-

tween two analogous muscles, and even between the corresponding ones of the two sides of the body.

Sympathies.

The animal muscular system performs a very important part in the sympathies. We see it very frequently agitated with irregular motions in the different affections of our organs, especially in infancy when every lively impression made upon any organ, is almost always followed by spasmodic and convulsive motions in the muscles of animal life. Observe in fact that it is the vital property predominant in this system, that is to say the animal contractility, that is most often brought sympathetically into action in it, by the influences that the organs exert upon each other.

In general it appears that when the animal sensibility is strongly developed in an organ, this system tends immediately to contract. The acute pains that stones occasion in the kidneys, in the ureter and even the urethra, distensions of the ligaments, of the aponeuroses, dentition, surgical operations in which the patient has suffered much, &c. produce very numerous and frequent sympathetic convulsions. I know that there are very severe pains without sympathetic convulsive motions; but it is very rare that you see convulsive motions of this nature, without the organ, from which these sympathetic irradiations go, is very powerfully affected, and the seat of great animal sensibility.

Observe on the contrary that most of the sympathies which develop to a great degree in any part, insensible organic contractility, or sensible organic contractility, are not marked by these acute pains in the affected organ from which the excitement goes; for example, sweats, sympathetic secretions, intestinal and gastric contractions are rarely produced by affections of the character of those from which arise the sympathies of animal contractility.

The brain is always first affected in this last species of sympathies in which the muscles are, as it were, passive, as we have already seen, and in which they are made to obey the impulse they receive. The affected organ acts at first upon the brain, then this re-acts upon the muscles.

Authors have considered sympathies in too loose a manner. Some have admitted, others have rejected the intermediate office of the brain; some have not pronounced upon it. All would be agreed, if instead of attempting to resolve the question in a general manner, they had distinguished the sympathies according to the vital forces, of which they are only aberrations and irregular developments; they would have seen, that in the animal sympathies of contractility, the cerebral action is essential; for we cannot conceive of any contractility of this species, without the double influence, nervous and cerebral, upon the muscles; that on the contrary, in the organic sympathies of contractility, the action of the brain is nothing; the affected organ acts directly and without any thing intermediate upon that which contracts sympathetically. When the heart, the stomach, the intestines, &c. move, when the parotid and other glands increase their action by the sympathetic influence of an affected organ, certainly this organ does not act first upon the brain; for it would then be necessary that this should re-act upon those that contract; now it would not be able to influence them except by the nerves, since it is only by these that it is united to them; but all experiments and all facts prove as we shall see, that the brain has not by this means any influence over the organs with involuntary motions; then the action is direct and there is nothing intermediate. There are sympathetic motions like the natural ones; the sensible and insensible contractilities are constantly brought into action by a direct stimulus applied to the organ, whilst that the animal contractility is never exercised but by the cerebral stimulant, which itself requires

a cause, either sympathetic or direct, in order to act upon the muscles.

Next to animal contractility, the sensibility of the same nature is the most often brought sympathetically into action in the animal muscular system. The lassitude, wandering pains, sensation of weight and stretchings that are felt in the limbs in the beginning of many diseases, are phenomena purely sympathetic, in which this property enters into action in the muscles. At advanced periods of many other affections, these sympathetic troubles are also very remarkable, but less in general than at the beginning.

The organic properties are for the most part rarely sympathetically in action in the species of muscles of which we are treating. Besides, if they are so, we can hardly judge of it, because no sign points it out to us. The sweat in the skin, the secreted fluids in the glands, the fluids exhaled upon many of the surfaces, are general results which indicate to us the sympathetic derangements of the organic sensibility and of the insensible contractility of the same species. In the muscles, we have not the same means of knowing these alterations.

Characters of the Vital Properties.

From what we have thus far said, upon the muscular properties and sympathies, it is easily seen that the vital activity must be in general much greater in the muscles than in the organs previously examined in this volume; thus all their affections begin to take a peculiar character that distinguishes them from those of these organs; they are much more prompt and rapid. Yet let us remark that all the alterations of function which they exhibit, cannot assist us in estimating this vital activity. In fact, many of these alterations do not reside essentially in the muscular texture, their cause is not there; such are for example all the convulsive motions in which, as

we have seen, the muscles act by obeying, but have not the principle of action in them. They are then the indices of cerebral alterations; thus the arteries, which exhibit such numerous varieties in the state of the pulse, are as it were only passive, and serve most frequently merely to indicate the state of the heart by their motion, whilst the veins, which have not at the origin of their circulation an analogous agent of impulse, very rarely exhibit varieties, though however their texture may have as great vital forces, and its life be as active or more so, than that of the arteries.

One proof that the texture of the muscle is less often altered than it at first seems to be in considering the frequency of the affections of these organs, is the infrequency of their organic lesions. These lesions are even less common in them than in the bones. We do not see in them those schirri, swellings, changes of texture in a word, which are so commonly met with in the other organs. Among the great number of subjects that I have had occasion to dissect or to have dissected, I do not recollect to have seen in the muscles of animal life other alterations than those of their cohesion, their density and their colour. It is a phenomenon that approximates them to those of organic life, in which we rarely meet with changes of texture, as the heart, the stomach, &c. are examples.

The muscular texture of animal life rarely suppurates; thus but little is known of its mode of suppuration. In general, it appears that inflammation terminates in it almost always by resolution. Induration, gangrene and suppuration, three terminations that this affection often makes in the other parts, are unknown to this in the greatest number of cases.

ARTICLE FOURTH.

PHENOMENA OF THE ACTION OF THE MUSCULAR SYSTEM OF ANIMAL LIFE.

Thus far we have spoken of muscular mobility, abstractedly from the phenomena that it exhibits in the muscles, when it is in exercise in them. These phenomena are now to be considered. They relate especially to contraction, which is the essentially active state of the muscle, relaxation being a state purely passive. We shall easily understand the phenomena of this, when those of the other of which they are the reverse are known to us.

I. *Force of the Muscular Contraction.*

The force of the contraction of the muscles of animal life varies much, according as it is brought into action by stimulants, or by the cerebral action.

Every irritation made upon a muscle laid bare produces only a brisk, rapid motion, but generally not very powerful. I have frequently satisfied myself in my experiments that it is impossible to approximate even at a great distance by this means, the great energy which the brain communicates to the muscles of animal life. The organic muscular system which stimuli directly applied put principally in motion, never has exacerbations of force corresponding to those which the animal contractility exhibits in so great a degree under certain circumstances. It is then especially when the muscles move in virtue of this last property, that the force of their contraction must be considered. Now this contraction can,

as we have seen, be produced, 1st, by stimulating the brain in experiments; 2d, when its excitement takes place in the natural state by the will, or by sympathy. In the first case, the force of the contraction is never very powerful, whatever may be the stimulant employed, either upon the brain, or the nerves laid bare. I have uniformly observed a very rapid convulsive motion, analogous to that produced by exciting the muscles themselves, but never as strong as that which is the result of vital action. Notwithstanding what some physiologists have written, we can never by irritating the nerves of the flexors impart to them an energy comparable to that which the will can give them. Irritate for example the sciatic nerve in an inferior extremity which has just been amputated, the toes will never bend with the force which they do in certain cases in the natural state. I have twice made this experiment in amputations performed by Desault. Unacquainted then with physiology, I was much struck with this phenomenon.

In the cerebral excitement and in that of the spinal marrow, we cannot so well appreciate the force of the contractions which result from it, as when we stimulate an insulated nerve; in fact, all the system entering then into convulsive action, the extensors destroy in part the effort of the flexors and vice versa. The muscles simultaneously in action, counterbalance, interfere with and injure each other. The stimulant which gives the greatest force to the contractions, has always appeared to me to be galvanism.

In the living state, the force of muscular contraction depends on two causes; 1st, on the muscle; 2d, on the brain. These two causes are in a variable proportion; it is necessary to consider them separately.

Under an equal cerebral influence, a muscle well nourished, which appears distinctly through the integuments, and has very large fibres, will contract much more strong-

ly than that which is delicate, slender, with loose, pale, small fibres, and which makes but a slight prominence under the integuments. In our ordinary manner of considering muscular force, it is to this state of the muscles that we especially attend. The statues which exhibit strength and vigour, have always as an attribute a powerful development of the muscular forms. When the brain acts upon these muscles with energy they are capable of extraordinary motions. I shall not relate examples of the astonishing efforts of which they are susceptible. Haller and others have cited many of them, either in the muscles of the back in carrying burdens, or in the muscles of the superior extremities in raising great weights, or in the inferior extremities in leaping or in order to preserve attitudes which suppose enormous resistances to be overcome.

It is especially the cerebral influence that increases much the force of muscular contraction. The will can raise this force very high; but the different excitements that are foreign to it, raise it infinitely more. We know the force that a man acquires in anger, that of maniacs, of persons in the cerebral excitement of a fever, &c. In all these cases the impulse communicated by the brain, is sometimes such, that the most delicate muscles of the feeblest woman surpass in energy those of the strongest man in the ordinary state.

The force of muscular contraction is then in a ratio compounded of the force of the organization of the texture of the muscles, and of the force of the cerebral excitement. If both are slight, the motions are almost nothing; if both are at the highest degree, it is difficult to conceive how far the effects may go which result from them; a maniac with thick and strong muscles is capable of efforts that we should in vain attempt to calculate. If the nervous force is very powerful, and the muscular texture feeble, or if an inverse state exists, the phenomena

of contraction are less. In general nature has almost always united these two things in this last manner. Women and children who have a weak fleshy texture, have a very great nervous mobility; men on the contrary, those especially with athletic forms, whose nervous systems are less easily excited, receive more rarely the causes of a strong influence upon their muscles.

Whatever may be the point of view in which we consider the force of the contractions of the muscular system of animal life, it is always very great in proportion to the effect which results from these contractions. Nature in the economy follows a law the reverse of that of the motion of our common machines, the great advantage of which is to increase the moving powers, to produce a great effect with a small force. Here there is always a great expenditure of force for a small effect, which is owing to the numerous causes that tend to destroy the effect of this force. 1st. The muscles act almost always upon a very unfavourable lever, upon that in which the power they represent is nearer the point of support than the resistance. 2d. All in contracting have to overcome the resistance of the antagonists. 3d. As in each motion there is always a fixed point, the effort which, after contraction, is carried upon this fixed point, is entirely lost. 4th. Various frictions injure also the motion. 5th. The obliquity of the insertion of the muscles upon the bones, an obliquity that approaches nearer a horizontal than a perpendicular direction, an obliquity not less remarkable for the fleshy attachments upon the tendon or aponeuroses, offers a double cause of weakness. All these and many other reasons which we might with Borelli, who was the first to make these important remarks upon muscular motion, add to them, prove that the absolute or real force of the muscles is infinitely superior to their effective force. Yet all are not so unfavourably arranged; in some, as the solæus, the insertion is perpendicular to the

bone; in others, as the muscles which act upon the head, we observe that they are powers of a lever of the first kind. In general, in order to estimate the force of a separate muscle, the deltoid, for example, it is necessary especially to have regard to the distance of its insertion at the point of support, to the degree of opening of the angles formed by the fleshy fibres upon the tendon, and afterwards by the tendon upon the bone, and to the division of the forces between the fixed and moveable points.

Some advantages seem to compensate in a slight degree in certain muscles for their bad arrangement as to the power of motion; such are, 1st, the sesamoids, the patella, the different eminences of insertion, the enlargement of the large bones at their extremities, &c. which remove the fibres to a distance from the moveable points; 2d, the intermuscular fat, that which is in the neighbourhood of the muscles, the fluid of synovial sheaths, which facilitate motions by lubricating the surfaces that execute them; 3d, the aponeurotic expansions that confine down the motions on the extremities; 4th, these motions themselves, those of flexion for example, which, as they take place, diminish the obliquity of the insertion of the flexors, and render it even perpendicular, as has been well observed by a modern author.

Many calculations have been made upon the waste of muscular motion, upon the effort of a muscle which contracts, compared with the effect that results from it. They can never be precise because the vital forces vary to an infinite degree, because they are not the same in two individuals and beccause the cerebral influence and the force of muscular organization are never in constant proportion in the same subject. It is a peculiarity of the vital phenomena to escape all calculations, and to exhibit, like the forces from which they emanate, a character of irregularity which distinguishes them essentially from the physical phenomena. Let us conclude only from the pre-

ceding observations, that the muscular effort carried to the highest point by cerebral excitement, can produce astonishing effects, which suppose a force of contraction hardly conceivable; such is the rupture of the strong tendons, of the patella, the olecranon, &c.; such is also the resistance often opposed to the enormous distensions that are used in luxations, fractures, &c.

II. *Quickness of the Contractions.*

The contractions should be considered under the relation of their quickness as under that of their force.

1st. If it is by stimulants that they are produced, by laying bare a muscle and acting directly upon it, they vary according to the state of vitality of the muscle, and according to the body which stimulates. In the first moments of the experiment, they succeed with rapidity and are sometimes connected together with such quickness that the eye can hardly follow them. As the muscle becomes weak, its contractions become less prompt; and they cease at the end of some time. We can reanimate them by employing a very active stimulant; the fibres finally become insensible to this also.

2d. If it is by irritating the nerve that we make a voluntary muscle contract, we produce a still greater quickness of contraction than by stimulating the muscle itself. Running would be almost immeasurably rapid, if each contraction that it requires was equal to those that we thus obtain, especially when we act on the one hand on very sensitive animals, and on the other with very active stimulants, galvanism for example. Upon this subject I have made a remark, it is that the quickness and the force of the contractions are not commonly greater if we irritate at the same time all the nerves that go to a muscle, than if we irritate but one.

3d. When it is the will that regulates the quickness of the muscular contractions, this quickness has infinitely

various degrees; but there is always one beyond which we cannot go. This degree is not the same for all men; there is even among them in this respect very great differences, which are foreign to the force of organization of the muscles; it is rare even that individuals with a very powerful muscular system are the best runners. I do not know that we have yet observed the exterior habit of the body which indicates the quickness of the contractions, as there is one which denotes their force; it must however exist. Animals are like men; the degree of quickness which each can attain, is infinitely variable. I shall not cite examples of rapid races, of analogous motions given by the superior extremities, as those of the fingers in performing on certain instruments, the violin, the flute, &c.; astonishing ones may be read of in many authors. I would only remark, that there are but few motions which give us a greater idea of this quickness, than the sudden and rapid contractions which, in the inferior extremities, produce a leap, or that powerful action of these extremities when we give a kick with the foot; which in the superior serve for the projection of heavy bodies; which in the same limbs assist to push the trunk back, when we support them against a resisting point, and afterwards suddenly stretch them to push this point forward, which not yielding, the motion rebounds upon the trunk; which preside over the action of giving a blow of the hand; which in the fingers produce the sudden motion, from which results what is called a fillip, &c. &c. I confound all these motions almost entirely analogous to leaping, and which differ from it only in the more or less evident effects that they produce. Authors, it may be observed, have not sufficiently established the resemblances between these various sudden and rapid contractions; they have considered leaping in too insulated a manner. But let us return. The degree of rapidity of muscular contractions is greatly subordinate to exercise. The habit

of making certain muscles act renders them more quick in their contraction; for example, walking which accustoms us to contract alternately the extensors and the flexors of the lower extremities, fits us wonderfully for swiftness in running. When any man practises for a little time this last exercise, he soon attains the greatest rapidity of which his muscular system is capable. On the contrary, the motions of adduction and abduction being more rare in the ordinary state, it requires a longer apprenticeship for dancers to learn to carry their legs rapidly in and out, for the purpose of executing steps in which they cross them alternately. In general, habit modifies much more the quickness than the force of the contractions. Yet there is always a limit which can never be passed, whatever may be the exercise that we give to the muscles; this limit depends on the constitution; each man is by it, a more or less active leaper and runner.

III. *Duration of the Contractions.*

There is as it respects the duration of the contractions a remarkable difference in the muscles, according as we excite these contractions artificially or naturally.

When upon a living animal or one recently killed, we excite the muscle itself, or we stimulate its nerves, the relaxation succeeds almost suddenly the contraction; neither state is ever lasting, though we continue for a long time the action of the stimulant; the effect which it has produced is immediately exhausted. When galvanism, mechanical or chemical agents are used in our experiments, the phenomenon is the same.

On the contrary, when the will directs the contraction, it can sustain it for a very long time. The support of burthens, standing, &c. clearly prove this fact. When even during life, a morbid irritation is directed upon the nerves, the contraction can be very permanent, of which we have terrible proofs in tetanus.

The permanence of the muscular contraction fatigues the muscle much more than alternate relaxation and contraction. Hence why when we are standing long, we contrive by turns to carry the weight of the body more upon one limb than the other.

IV. *State of the Muscle in Contraction.*

Muscles that contract exhibit different phenomena as follows:

1st. They evidently harden, as we may be convinced by placing the hand on the masseter, the temporal or any other superficial muscle in contraction.

2d. They increase in thickness; hence the greater prominence of all the sub-cutaneous muscles when the body is in violent action. Sculptors know this difference very well. A man at rest and a man in motion, have in their statues an exterior wholly different.

3d. The muscles when they are not confined by the aponeuroses, sometimes experience a slight displacement.

4th. They diminish in length, and thus the two points to which they are fixed approximate.

5th. Their volume remains about the same. What they lose in length, they nearly gain in thickness. Is the proportion very exact? Of what consequence to us is this insulated question, to which, since the days of Glisson, so much importance has have attached! it deserves none.

6th. The blood contained in the vessels of the muscles, especially in the veins, is in part pressed out; we increase the flow of the blood by the motions of the arm, the operation of bleeding proves both these facts.

7th. Yet the muscle does not change colour; it is because it is not the colouring portion of the blood circulating with it in the muscular vessels that colours the muscles, but, as I have said, that which is inherent in their texture and combined with their fibres; now this

combined colouring substance remains the same in relaxation and contraction. The heart of the frog is pale when it contracts; but it is because the blood it contains is evacuated and the transparency of its parietes renders this phenomenon evident.

8th. In contracting, the muscles become the seat of many small transverse wrinkles, sensible especially in the contractions of oscillation, less apparent in those of the whole of the muscle, and almost nothing, when a muscle being laid bare in a living animal, contracts with a small degree of force.

9th. All authors consider contraction in too uniform a manner; they have described the phenomena of it, as if in every case the muscle contracted alike; but it is evident that there are numerous differences in the state in which it then is. 1st. There is the slow and insensible contraction produced by the contractility of texture, when we cut a muscle or when its antagonist is paralyzed. 2d. The quick and sudden contraction produced by the will, or by the excitement of a nerve, a mode of motion that takes place most commonly either in the ordinary state, or in convulsions. 3d. The species of oscillation of which I have already spoken, and which affecting each fibre in a muscle, does not yet produce any very sensible effect upon the whole, contracts it a little, but scarcely approximates at all its moveable points; this is the kind of motion which takes place in the tremors produced by cold, by fear, by the beginning of a fit of intermittent fever, &c. By laying bare a muscle in an animal that is made to shiver, we see that this kind of contraction resembles precisely that which is produced by pouring salt in powder upon a part of the muscular system. Then, although there may be in all the muscles, an internal motion infinitely more sensible than in the great contractions, yet the limbs are displaced but little, there are hardly any motions of the whole muscles, they are but slight jars.

4th. There are other modes of contraction less sensible than these, but which however exhibit differences. In general, to each species of motion of the muscle is adapted a particular manner of contracting; if we make but few experiments on living animals, we may easily be convinced how much the most judicious authors have been mistaken upon this point.

Two modes of contraction are often combined; for example, when we cut a muscle transversely in a living animal, there is at first a slow contraction of the whole, produced by the contractility of texture, then partial oscillations in all the divided fibres; now these oscillations are foreign to the retraction which takes place without them, often in the living animal and always in the dead body. So the oscillations can be combined with the sudden contraction arising from the nervous influence by the act of the will, or they may be disconnected with it, as happens almost always when the animal is in full life. We may be convinced of this last fact without recourse to experiments, by placing the hand upon the masseter muscle or the biceps of a thin person when they are contracting; we do not feel in them through the skin any motion analogous to these oscillations.

V. *Motions imparted by the Muscle.*

Every muscular motion is either simple or compound. Let us now speak of the first; by it we shall understand the second.

Simple Motion.

It must be considered, 1st, in the muscles with a straight direction; 2d, in those in a reflected one; 3d, in those in a circular one.

In the first, as in those of the extremities, the trunk, &c. if they are of an elongated form, and as they termi-

nate by a tendon, each fibre contracting draws this tendon from its place; whence it follows that all act together to bring it towards the centre of the muscle, but at the same time each of them tends to give it another direction, and in this respect they are antagonists. The common motion remains; the opposite is destroyed.

Every effort of contraction in the long muscles is concentrated upon a single point, the tendon. In most of the broad muscles, on the contrary, the attachments being made at two sides by different points, all the fibres do not contribute to the same end. Thus the different parts of the same muscle can have very different and even opposite uses; thus the inferior portion of the great serratus does not act like the superior; often even the different portions of the same muscle do not contract at the same time. In a long muscle, on the contrary, as all the fibres contribute to produce the same effect, they always act simultaneously.

To estimate the effect which a muscle in the straight direction produces upon the bones in which it is inserted, different means are employed. A very simple one appears to be that, which I believe has never been mentioned. It consists in examining the direction of the muscle from its fixed to its moveable point, and in taking the inverse of this direction; this last is always the direction of the motion. Do you wish to know how the anterior radial acts upon the wrist; take it at its insertion at the condyle, then follow its direction downwards and outwards; you will see that it carries the hand upwards and inwards, that it bends it and places it a little in adduction. The tibialis anticus directed downwards and inwards raises the foot and carries it outwards. The anterior rectus of the thigh going straight from the pelvis to the patella, raises the leg directly up. All the other muscles will exhibit this arrangement. Whatever may be the attachment of their fixed or moveable point, they always

act inversely to the supposed line of direction going from the first point; and as each attachment can be alternately moveable or fixed, the two bones which serve them are carried in an opposite direction; the coraco-brachialis directed downwards and outwards from the shoulder towards the arm, carries this last upwards and inwards; directed from below upwards and from without inwards from the arm towards the shoulder, it moves this downwards and outwards. By this general rule, it is sufficient to see a muscle in a dead body, to pronounce upon its uses.

When the whole of a broad muscle is united at a common point, as the deltoid which having many points of attachment above, is fixed below in a single tendon, the middle line of direction of all its fibres should be taken to estimate its uses.

When a muscle is attached by its two extremities at many points, and consequently the fibres that compose it, form many fasciculi with different directions and insulated motions, the line of direction of each fasciculus must be examined in order to estimate the action of the muscle. It is thus that we should study that of the trapezius, the great serratus, the rhomboid, &c.

In the muscles with reflected direction, as the great oblique of the eye, the lateral peronei, the circumflexus, &c. the action of the muscle should only be estimated by the point of reflection; thus the great oblique carries the eye inwards, though its fleshy portion contracts so as to carry the moveable point backwards.

The orbicular muscles, those placed around the lips, the eyes, the anus, &c. have in general no fixed or moveable points; they are not designed to approximate two parts to each other, but only to contract the opening around which they are situated. The anus is shut by its sphincter, when the excrements do not dilate it. The mouth remains closed, when the depressors, the elevators

or the abductors of the lips are inactive. The eye is shut, when the elevator of the superior eyelid is relaxed. I would remark upon this subject that the inferior eye-lid having no depressor, it is principally the other which contributes to shut or open the eye; and as its muscle cannot be in permanent contraction, the alterations of its relaxations produce those continual winkings which take place when the eye is open; they are to the eye what the alternate change of the weight of the body from one leg to the other is in long standing without motion. At every instant the muscle relaxes; the sphincter acts immediately; then it contracts and distends the sphincter; winking then is a continual struggle between the elevator of the eye-lid and the orbicularis. In sleep, it is not by the contraction of this that the eye is shut; it is relaxed like all the muscles; it is because the elevator is inactive, that the eye-lid falls by its own weight upon the eye; it communicates as it were the motion to the orbicularis that it shuts up, whilst, during the day, it is the orbicularis on the contrary that communicates this motion to it.

Compound Motions.

There are but few motions in the economy that are simple, but few muscles that can contract separately. Almost every sort of contraction supposes another, and for this reason; the two points to which a muscle is ordinarily attached are both capable of being moved; if one of them was not fixed, both would then be put in motion when the muscle contracted; thus in the contraction of its extensors, the leg if it was not fixed would approach the foot as much as the foot approached the leg; now it could not be fixed but by the muscles which act in an opposite direction to the effect which the extensors tend to produce upon it; then whenever the two attachments of a muscle are moveable, the insulated motion of one of

them supposes the contraction of different muscles to fix the other.

It is only those muscles that are attached on one side to a fixed point and on the other to a moveable one, like those of the eye, and most of those of the face, that can move in an insulated manner, and without requiring a motion in the other muscles. It should be remarked however that in general the contractions destined to fix the point which should be immoveable in the ordinary motions, are less than they at first seem to be. In fact, in these ordinary motions, the point which moves is always the most moveable, that which remains without motion is the least so; for example, it requires a much greater effort in flexors to bend the arm upon the fore-arm, than to bend the phalanges upon the fore-arm, or the fore-arm upon the arm. By supposing their two attachments moveable, the gemelli would act much more powerfully on the foot than on the femur, &c. In the extremities, the superior point is always more moveable than the inferior, now it is this which almost always moves, the other being fixed; then as it offers more resistance by its position, it requires less effort of the muscular powers to retain it. It is only in violent motions, that the previous contraction of the muscles destined to fix one of the points of insertion is very painful. This takes place on the chest when the trapezius, the great serratus and the great pectoral contract powerfully; then all the other muscles of this cavity contract strongly to dilate it, and thus offer a broader and more fixed attachment to those muscles, which move the shoulder in the support of burdens, or in any other analogous effort. The diaphragm contracts also; hence hernias, the descents which take place from a concussion in those motions which, at first view, have no analogy with the abdominal cavity. When in a horizontal posit on of the body we raise the head, the recti

muscles of the abdomen contract to fix the chest, and present a solid point to the sterno-mastoideus, &c.

We call especially a compound motion that which two or more muscles, acting upon the same point, contribute simultaneously to produce. In this case, the moveable point follows the direction of neither muscle, if there are two of them, but takes the diagonal of their direction. It is thus that the eye is moved outwards and upwards, outwards and downwards, &c.; that the head is depressed, that it is carried to one side, and that the arm is applied to the trunk, &c. In general nature has distributed muscles only in some principal directions around a moveable point, for example around the eye, in those of elevation, depression, adduction and abduction; the combination of these simple motions produces the compound ones. If the adductor and depressor contract equally, the eye will be carried exactly in a middle direction; if one acts with more force than the other, it will be carried a little nearer the other; so that the four muscles, by moving separately, or two by two in an equal manner, carry the eye in eight different directions. In all the intermediate directions, there is also a simultaneous action of two muscles, but always a superiority in the action of one of them. Thus almost all the motions of circumduction operate.

When two opposite muscles contract, the moveable part is not moved; they are perfect antagonists. When two muscles which contract at the same time are placed in the same direction, there is no loss of power; this is what takes place when the genio-hyoideus and the mylo-hyoideus depress the jaw or elevate the os hyoides; these muscles act completely together. But when two muscles are in part opposed and in part in the same direction, as the sterno-mastoidei, one portion of the forces is destroyed and the other remains. The action by which the sterno-mastoidei tend to carry the head to the right or the left,

is nothing; that alone by which they direct it downwards produces its effect which is double, considering the action of the two muscles, which are thus at the same time acting together and antagonists. Hence we see that this applies not only to the motion produced by the contractility of texture, but also very often to those which the animal contractility occasions.

VI. *Phenomena of the Relaxation of the Muscles.*

When a muscle ceases to contract, it becomes the seat of phenomena precisely opposite to the preceding, which it is sufficient to know in order to understand these. The muscle becomes longer and softer; its wrinkles disappear; it returns exactly to the state in which it was found. It is needless to give in detail the series of these phenomena.

I would remark that in the state of relaxation of the muscles, the parts often execute motions which are only owing to their weight; such are the flexion forwards of the head in sleep, the fall of the fore-arm and the arm in the same case. Then the weight is often opposed to the limbs, remaining in their middle position, which are not supported. We see particularly these phenomena in paralysis.

ARTICLE FIFTH.

DEVELOPMENT OF THE MUSCULAR SYSTEM OF ANIMAL LIFE.

The muscular system exhibits great differences, according as we examine it before the completion of growth, or

in the ages that follow that in which this growth is terminated.

I. *State of the Muscular System in the Fœtus.*

In the first month of the fœtus, this system is, like the others, a mere mucous homogeneous mass, in which can be distinguished scarcely any line of demarcation. Aponeuroses, muscles, tendons, &c. all have the same appearance. Gradually the limits are established, the muscular texture at first takes a deeper tinge, from the blood that enters it. Yet this tinge is at first much less evident than in the adult; it remains nearly the same till birth. If we make use of the bones as a means of comparison, this becomes striking. In the adult the interior of the bones is less red than the muscular texture; the difference is remarkable. It is the contrary in the fœtus; much more blood penetrates the already ossified portion of the bones, than the interior of the muscles. Nature distributes the blood in an inverse manner at these two periods of life in these two systems.

I presume that this phenomenon is principally owing to the kind of inertia in which the muscles remain before birth. Observe in fact that though some motions announce in the last months the presence of the fœtus in the womb of the mother, yet these motions are infinitely less than they are to be afterwards. The proof of this is the constant semi-flexed position which the limbs and trunk have, and the small space that there is to execute these motions in, especially in the last periods in which the waters are wonderfully diminished. In the early periods of pregnancy, though the space may be greater, by opening the females of animals, we constantly find the fœtus drawn up upon itself, and in an attitude almost immoveable.

Many respectable philosophers have found the muscles of the chick in its shell much less irritable than after

birth, either by ordinary agents, or by galvanic influence. I have made the same experiment upon small guinea-pigs that were never born, by irritating directly their muscles, or by stimulating their nerves, their spinal marrow and the brain. The nearer we approach the term of conception, the less are the motions obtained. That which is especially remarkable is the rapidity with which, when the fœtus is dead, the muscles lose their irritability; the instant that extinguishes life seems to destroy this property. In the latter periods that precede accouchement, it is a little more permanent, and more susceptible of being brought into action, but always less than after birth. We can hardly doubt then that the motions are less at this age, though however they exist. We shall see that the nutrition, size and redness of the muscles are in general in the adult in proportion to the number of the motions they perform; it is not then astonishing that less blood penetrates them in the fœtus. Besides the nearer we approach the period of conception, the less abundant is this fluid in them. I have had occasion to make this remark on guinea-pigs killed at different periods of gestation. In the early periods, the muscles of the small ones really resemble those of frogs; white like them, they are marked with reddish lines, which indicate the course of the vessels.

I presume also that the kind of blood which circulates at this age in the arteries and which penetrates the muscles, is less proper to support and develop their mobility. In fact it is the black blood that then enters the muscles by the vessels. We know that in the adult, whenever this blood circulates preternaturally in the arterial system, life is altered, the muscular motion is weakened, and soon asphyxia comes on. It is to the nature and the colour of the blood of the fœtus, that must be attributed the livid and often deep tinge that its muscles exhibit; for this is also a character that distinguishes them

from those of the adult. Not only their colour is less evident and they are paler, but their tinge is wholly different; and this tinge has uniformly the character of that of the fœtus before it has respired.

The muscles are slender, but little developed in the fœtus. Their development is infinitely less than that of the muscles of organic life. The size of the limbs arises especially from their sub-cutaneous fat. When this fat is in small quantity, and we compare the limbs with the trunk, they are much less in proportion than they will be afterwards. In the fœtuses that have much cutaneous fat, from whom we remove all the skin, we also see this disproportion of size. We know that at this age all the cavities of muscular insertion, all the apophyses destined to the same use, are almost nothing. The parietes of the temporal fossa, for example, more curved outward, enlarge the cerebral space, and contract that which the temporal muscle fills. This is a small anatomical fact which is the consequence of a great law of nutrition, viz. of the predominance of the nervous system to which the brain belongs, over the animal muscular, in respect to development. Let us remark that this predominance, whence arises at this age an evident disproportion between the muscular and nervous systems, when compared to what they will be afterwards, would alone prove that the muscles are not, as has been said, a termination and expansion of the nerves; in fact two species of organs whose development is inverse, cannot belong to one and the same system.

Many authors have pretended that the fleshy portion was in proportion much more developed in the fœtus than the tendinous, that this even did not exist. I cannot imagine whence this opinion arose. It may be conceived that they have thought that the aponeuroses of the limbs were wanting in the first months; I have uniformly observed that they have not then that white colour which

characterizes them afterwards, a colour that they only take when their fibres are developed; they are transparent, like a serous membrane, and cannot at first sight be perceived. But the tendons have a very evident white colour; we distinguish them very well; they are quite as large and as long in proportion as they will be afterwards.

II. *State of the Muscular System during Growth.*

At birth, the muscular system of animal life experiences, like all the others, a remarkable revolution. Until then black blood only penetrated its arteries; then the red blood immediately enters them; for this blood is formed when respiration takes place; now this takes place in almost all its perfection at the very instant the fœtus leaves the womb of the mother. We evidently see besides that the livid tinge of the skin gives place almost immediately to a red colour, which arises from this difference of the blood. This new fluid entering the muscles, is a new cause of excitement, and consequently of motion. Add to this cause the sudden increase of cerebral action. Till then, the brain penetrated with black blood, was as in a kind of inertia, which was principally owing also to the absence of sensations, as I have elsewhere proved. Suddenly the red blood enters it; it stimulates it either by the principles that it contains, or because it was different from that which had penetrated it; for such is the nature of sensibility that it is capable of being affected in an organ, merely because the stimulus that is applied to it is new. Suddenly excited by the red blood, the brain re-acts upon the muscles, and determines them to contract. This cause, joined to the preceding, appears to me to be one of those which have the most influence on the sudden disappearance of the kind of inertia in which the fœtus was, or at least of the small degree of motion that it performed, by the general agita-

tion of its limbs, its abdomen, chest, face, &c.; for immediately after birth all the muscles are moved more or less strongly.

Let us not, however, exaggerate the influence of a cause which is certainly not the only one; for example, the motions of the diaphragm and the pectoral muscles, are certainly prior to the entrance of the red blood in the brain, since their action is necessary to the production of this red blood. These muscles enter into action, because the excitement of the air on the whole exterior of the body, and on the mucous membranes in contact with this fluid, stimulates the brain which is the centre of all sensation. Moved by this excitement, this organ reacts upon the muscles, and begins to make them contract. The contractions increase, when to this external and indirect excitement is added the internal and direct excitement of which we have just spoken. This second excitement is not absolutely necessary for the fœtus, for we often see infants that remain livid some instants after birth, move very well; but in general the motions are not so decided as when the red colour of the skin indicates the entrance of the arterial blood, which has undergone the influence of respiration.

The entrance of the red blood into the muscles does not give them immediately the colour they will afterwards have. For some time after birth, they have a deep tinge, as dissections clearly prove, because, as I have said, their colour does not come from the colouring portion circulating in their texture, but from that combined with this texture. Now nutrition alone produces the combination; but this function takes place gradually; it is truly a chronic function, in comparison with exhalation, absorption, and the circulation, which are evidently rapid in their progress.

As we advance in age, the muscles assume a redder tinge; more blood penetrates them; they are nourished

in proportion more than various other organs. This is particularly remarkable in those of the lower extremities. I would remark, however, that as long as growth continues, it is especially upon the length and not upon the thickness of the muscles, that the energy of nutrition is carried. Hence why they are but slightly visible through the integuments and are scarcely at all prominent; why their forms are rounder and more graceful, but less masculine at this age. The exterior of a young man is in this respect wholly different from that of the adult, by considering each, separate from every cause that can have an influence upon their conformation. The external appearance of the infant and the young man is in general very analogous to that of woman.

Though we do not know so well the difference of the substances which penetrate the muscles in the first years and in the adult age, as we know it in the bones in which the addition of the phosphate of lime to gelatine exhibits a very striking phenomenon, yet we cannot doubt that these differences really exist. Treated by ebullition, combustion, maceration, &c. the flesh of the fœtus does not give the same results as that of the adult.

The broth made with the muscles of a young animal contains much more gelatine, a substance which greatly predominates at this period of life. It has less flavour than that of adult animals. The extractive substance consequently appears to be less. A mawkish, nauseous taste characterizes broths made of veal. The difference of the principles they contain has an influence even upon the gastric organs, of which they excite the contraction; they loosen the belly, as it is called, a phenomenon unknown to common broths. It does not appear that the fibrin is in as great a proportion in the muscles at this period of life; the following considerations make me think so.

1st. Instead of this substance, Fourcroy has found in the blood of the fœtus a soft texture, without consistence,

and like gelatine ; now the blood appears to be the reservoir of fibrin. 2d. The force and energy of the contractions are in general in proportion to the quantity of this principle contained in the muscles ; now this energy is small in the first age. 3d. The muscles burn then, and crisp and contract less than in the adult. I have even two or three times seen their texture, when placed upon live coals, become puffed up like gelatine treated in the same way.

In general it appears that this last substance occupies in the muscles the place the fibrous system is afterwards to hold in them. Those who frequent dissecting rooms, have observed, no doubt, that other things being equal, the muscles of young subjects putrify less quickly than most other substances, and that when they do, they give out a less fetid odour. We know that broth made of veal turns sour more easily than that made of beef. It is always whitish, and never has the deep colour of the broth made with this last. It becomes like jelly much more easily. Young and old roast meats exhibit also great differences. Every kind of stewing either by the fire alone, or in any fluid, is much quicker and easier in the first age. The gravy that is then extracted from the muscles has a character wholly different, it is less strong. The effects of maceration are also more rapid ; we obtain sooner that mucous pulp, to which the action of water finally reduces almost all animal substances.

III. *State of the Muscular System after Growth.*

After general growth is finished in length, our organs then increase in thickness ; and it is especially in the muscles that this phenomenon is remarkable. To the slender and delicate body and round forms of the youth and young man, succeeds a large, strong and thick body with well developed forms. The muscles can be traced

through the integuments, eminences and depressions are observed in them ; different depressed lines serve as limits to various prominent ones. The animal muscular system is then more prominent in a state of repose, than it is in youth in its greatest motions. Painters and sculptors have studied more than anatomists the different degrees of the development of the muscles.

The period when the hairs grow, when the genital organs begin to become active, is principally that in which the muscles begin to become prominent in man. In woman, this last period does not present a similar phenomenon ; the muscles preserve the original roundness, they scarcely ever lose it. In this sex, the roundness of the limbs, their agreeable forms, make a contrast with the kind of rudeness of those of man.

The increase in thickness in the muscles appears to be much more in the fleshy than the tendinous portion, and especially than the aponeurotic. The intermuscular aponeuroses principally do not appear to grow in proportion to the fibres that are inserted into them ; so that these make a prominence, and at the place of the aponeurosis there is a depression. This is what we see very well in muscles cut for their insertions by many of these fibrous expansions, in the deltoid in particular. Not only the prominence through the skin of the whole of the muscle, makes the depressions evident that separate it from the others, but each fleshy bundle has a prominence which a groove separates ; this, it is true, is only distinguishable upon thin subjects.

As the muscle grows in thickness, it increases in density. It becoms firmer and more resisting. If we place for comparison the hand upon two similar muscles of an adult and an infant, whilst they are in contraction, we feel a sensible difference in their hardness. Weights suspended for comparison to the muscles of the two ages, taken in the dead bodies, prove the different degree of their

resistance. The muscular texture of adults yields more slowly to all re-agents.

The colour of the muscles continues to be red in the adult; but in general, and all things being equal in respect to the causes that make this colour vary, it begins to become of a less bright red after the thirtieth year. It is usually in the last years of growth, and even from the tenth to the twentieth, that the colour is the most brilliant.

In the adult this colour exhibits a very remarkable phenomenon. All men have their muscles red, but hardly two have the same shade. Those who have opened many dead bodies are easily convinced of this; a residence at the dissecting rooms proves this assertion. A thousand causes have an influence upon this colour; the temperament is the principal. The external appearance of the muscles without the skin indicates by their shades of colour the temperament, as well as the integuments do. Diseases make this colour vary wonderfully. All those that have a chronic progress alter it remarkably; it then becomes pale, dull, &c. Dropsies whiten it, when they are of long standing. In general, every thing that has upon the powers of life a slow and debilitating influence, diminishes the brightness of it. Acute diseases, whatever may be their nature, change it but little. Fevers with the greatest prostration, if they suddenly produce death, leave it untouched, because this colour can only change by nutrition; now as this function is slow in its phenomena, it is but little affected by acute diseases; it is only at the end of some time that it feels the affections reigning in the economy.

I would observe that the varieties of colour that are seen in the muscles of adults, even in the healthy state, distinguish them especially from those of the fœtus, which have in general an uniform paleness. This difference is owing to the fact, that in the first age, we are not

subject to the action of the numerous agents which modify, in an infinitely variable manner in the after ages, the great functions, and of course nutrition which is the end of them. It is in these varieties of colour of the muscular system of the adult, that we clearly distinguish that the blood circulating in the arteries is wholly foreign to it; in fact it is uniform, and never partakes of those varieties of colour whatever they may be.

Many circumstances in the adult make the muscular nutrition vary; motion is the principal. The man who passes his life at rest is remarkable for the small prominence of his muscles, especially if we compare this prominence with that of the muscles of a man who takes great exercise. Not only general motion exhibits this phenomenon, but also local motion, as we see in the arms of bakers, the legs of dancers, the backs of porters, &c.

IV. *State of the Muscular System in Old Age.*

In old age, the texture of the muscles changes remarkably; it becomes resisting and stiff; the teeth tear it with difficulty. This too great density is injurious to its contractions, which can now only take place slowly; the action of the brain becomes less upon the muscles; the continuance of their motions is not as long; they are sooner fatigued.

I would remark that the density of the muscles should not be confounded with their cohesion. The first arises from substances that enter into the composition of the muscle. Cohesion on the contrary appears to be owing to vital influence, the effect of which is preserved after death. Dissect the muscles of a strong and vigorous adult; the fleshy mass is firm; it keeps in its place; it supports itself, though the scalpel may have removed from it every surrounding texture. On the contrary,

in a body dead of a chronic disease, in a dropsical or phthisical subject, the muscles are loose and cannot support themselves; the relations are destroyed when the surrounding texture is removed. The first subjects are much more suitable for the dissection of myology than the last. The muscular texture is in old subjects nearly as in these last, flaccid and loose; we feel this flaccidity under the skin in the solæus, the gemelli, the biceps, &c.; it does not prevent each fibre from being dense and tough. In general the muscular cohesion is in the inverse ratio of the age; the muscles of a young man are firm and compact; they are not moveable under the skin. Towards the fortieth year and afterwards, we begin to perceive more laxity; the calves of the legs vacillate in great motions; the glutei and in general all the prominent limbs exhibit also this vacillation, especially if the individual is thin. The muscles become more and more susceptible of moving thus, as we approach old age, a period in which the least motion makes the whole muscular system vacillate. Why? Because the muscle is no longer in sufficient contraction; it is as it were too long for the space it fills. This appears to be owing to the circumstance that the contractility of texture has diminished in the last age; we can be convinced of this by cutting transversely for comparison a muscle in an old man and a young one; it retracts more in fact in an opposite direction in the second than in the first. This contractility of texture approximates all the particles of the muscle when at rest; it can no longer produce this approximation; the muscle remains loose. Authors have not sufficiently observed this remarkable phenomenon which the muscular system experiences from the progress of age, a phenomenon which is really the index of its degree of contractile power.

Frequently in old age the muscular texture loses its colour and takes a yellowish one and has a fatty appear-

ance, though however this colour does not arise from the fat, but from the absence of the colouring substance of the blood. I have often made this remark. If we strip all the surrounding fat from these pretended fatty muscles, and leave them only their texture, combustion or ebullition extracts no animal oil from them; they are in their fibrous state as usual; the colour only is different. I have remarked that the deep muscles of the back and those placed in the vertebral depressions are much more subject than all the others to lose their colour and to exhibit this yellowish aspect, an aspect that is rarely ever seen in the whole system, but only in some insulated muscles. Adults are subject, though less frequently however, than old people, to this alteration. Many times we see limbs that are poorly nourished, with an aspect nearly the same. In recent palsies, in those even of three, four or six months, there is in general no change in the limbs; the muscles preserve their colour and their size; but at the end of a longer time, the absence of motion, perhaps also the deficiency of nervous influx, terminate by altering the nutrition left for a long time untouched without this influx, and then the muscles change colour, contract and diminish. But this phenomenon is not always constant, and there are at the Hôtel-Dieu hemiplegias of six, seven and even ten years, without the limb of the sound side predominating in its nutrition over that of the diseased one.

External pressures for a long time continued upon a muscle, produce nearly the same effect as want of nourishment; they discolour and whiten it by preventing the circulation in it. Those who make use of straps constantly passed under the arms, who habitually have girdles round the abdomen and who lift burdens, have often the muscles corresponding to the constant pressure they experience, in the state of those of old people. I

would remark that these muscles contract notwithstanding; which proves that the colouring substance is not of absolute necessity to muscular action.

The blood is carried in general in much less quantity in the muscles of old people; their vessels are in part obstructed; this is what disposes them to the state of which I have just spoken.

V. *State of the Muscular System at Death.*

At the instant of death, the muscles remain in two different states; sometimes they are stiff and inflexible; sometimes they allow the limbs to execute motions very easily. It is sometimes necessary to make an effort to bend the thigh of a dead body; at others the least touch is sufficient to do it, as for example in asphyxia, from charcoal. These state of rigidity and relaxation have infinite degrees. The first is sometimes so great, that the subject raised against a wall remains standing; at other times it is nothing. Some muscles are stiff in subjects, while others are relaxed. It appears that these different states depend upon the kind of death, upon the phenomena that accompany the last moments. But how do they precisely happen? It is an object of interesting research. I have remarked that the muscles remaining stiff at the instant of death, are often torn with ease, if we attempt to force the motions of the limbs to which they go; that the tearing hardly ever takes place on the contrary in those remaining supple, whatever may be the impulse communicated at their moveable points; it is necessary to draw them directly, attach weights to them, &c. to produce this phenomenon, which is then easy.

The muscular texture is never preternaturally developed in the different organs in which nature has not originally placed it, as happens in the osseous, cartilagin-

ous and even fibrous textures. If it were developed, it would not belong to animal but to organic life; because in order to depend upon the first, the cerebral nerves are essentially necessary, the muscle being but the agent of the motions which the latter communicate.

END OF VOL. II.